

CHEMISTRY



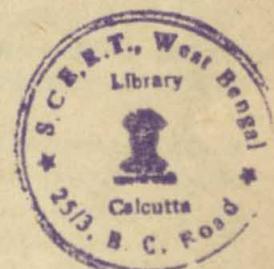
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CHEMISTRY

A TEXTBOOK FOR SECONDARY SCHOOLS

PART II

B.D. Atreya
R.D. Shukla
K.M. Pant



राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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Foreword

The *Ten-year School Curriculum—A Framework* (published by the NCERT in 1975), provided broad guidelines for developing a new set of textual materials in science for Class IX and X under the 10+2 pattern of schooling. Keeping in view the guidelines provided by the *Framework*, a textbook in chemistry for Class IX and X was developed by the NCERT through an Editorial Board, and published in 1977.

Curriculum development is an on-going process. Science syllabi for secondary classes were developed by the CBSE through their Committee of Courses in different subjects, during 1982. The NCERT subsequently collaborated with CBSE in this effort for curriculum revision. A National Seminar-cum-Workshop on Secondary Science and Mathematics Curriculum was organised in March 1984 to review the syllabi and draft textual materials, with a view to provide suggestions and guidelines for their improvement. The authors revised their textual content in the light of the suggestions made during the Workshop. As an outcome of these efforts, the chemistry textbook for Class IX was published in January 1985.

The present book is meant for Class X of schools following the syllabi of the CBSE. The members of the NCERT Committee for the Class X chemistry textbook and the participants of the National Workshop played a crucial role in the development of this book. The Council is thankful to all of them.

The NCERT is thankful to the CBSE for initiating this process of textbook revision in chemistry at Secondary level, for providing inputs—both expertise and materials—to the National Seminar-cum-Workshop, and for active collaboration throughout the development of the textbook in chemistry for Class X. My special thanks are due to the convener, Professor A.C. Jain, of the Delhi University, and also to the other members of the CBSE Committee of Courses in Chemistry. The Council is thankful to the authors of this book, namely Prof. B.D. Atreya, Prof. R.D. Shukla and Dr. K.M. Pant, for preparing draft chapters and finalising them on the basis of suggestions received from time to time. Thanks are also due to the members of the Chemistry Group of the Department of Education in Science and Mathematics for reviewing the chapters as a prelude to the National Workshop and for

providing other necessary assistance as and when requested.

Suggestions for further improvement of the book are most welcome.

New Delhi
January 1986

P.L. MALHOTRA
Director
National Council of Educational
Research and Training

Preface

This textbook is in continuation of Part I of the book written last year by the same authors for Class IX students. The present book follows the revised syllabus prepared by the Central Board of Secondary Education's (CBSE) Committee of Courses in Chemistry under the convenership of Dr. A.N. Bose, Professor of Chemistry, National Council of Educational Research and Training, reviewed in two workshops organised by the NCERT and the CBSE in August 1983 and March 1984, and finally accepted by the CBSE from the academic session 1985-86 onwards. This new course was designed with the following main objectives:

1. The course should provide a base for learning chemistry as related to economic development, environmental problems and national growth.
2. The course should develop a logical approach in solving problems in chemistry.
3. The course should provide a base for pupils who wish to take up chemistry at the plus two stage and it also should benefit those who are not going to continue to study the subject further.
4. The course should be backed by demonstrations and simple laboratory experiments in order to make the learning process easier for students.

The draft of the textual materials for the present book was prepared by the present authors as decided by the Chemistry Committee formed by the NCERT in its meeting held on 15 April 1985. Here, it is recorded with profound sorrow that the then Convener of this Committee, Professor S.R. Gupta of the Delhi University, could not attend this meeting as he was being hospitalised at that time and later expired on 23 April 1985.

The draft manuscript of the present book was reviewed in a National Workshop in Chemistry organised by the NCERT on 27-29 June 1985. The suggestions for revision and improvement made by the participants in the Workshop and also those made by the present Convener, who read the entire manuscript, were considered by the authors while finalising the manuscript.

As Convener of the CBSE Committee of Courses in Chemistry, I put on record my deep appreciation of the excellent work done by the present authors and of the wise counsel and administrative support given and the personal interest shown from time to time by Dr. P.L. Malhotra, Director, NCERT, Fr. T.V. Kunnumkal, Chairman, CBSE, Prof. A.K. Jalaluddin, Joint Director, NCERT and Prof. B. Ganguly, Head, DESM, NCERT. As the Convener and as an old friend of Prof. S.R. Gupta, I feel the vacuum created by his sudden and sad demise.

My sincere thanks are due to all the members of the NCERT Chemistry Committee, the CBSE Committee of Courses in Chemistry and the members of the National Workshop in Chemistry for their valuable suggestions for the improvement of the book. I take this opportunity to invite suggestions from both teachers and students for future editions of the book.

A.C. JAIN

*Professor of Chemistry
University of Delhi*

and

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CBSE Committee of Courses in Chemistry

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25 December 1985

**National Workshop for Refinement and
Finalisation of Textual Material
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UNIT 9

Metals

9.1 Introduction

You are familiar with the use of metals in our daily life. Most of the things we come across at home or outside are made of one or the other metal. Metals form an important component of the mineral wealth of a country. Some of the metals like iron, aluminium, copper, zinc, lead, tin, nickel, chromium, tungsten and platinum play a very vital role in several industrial processes such as the construction of agricultural machinery and implements, the making of transport vehicles and cutting tools, and for constructing equipment for use during both war and peace. Metals are also used as catalysts in a large number of industrial processes such as hydrogenation of vegetable oils, manufacture of ammonia and sulphuric acid, preparation of dyestuffs, organic solvents and life saving drugs and general medicines, manufacture of nitric acid and explosives. In a nutshell, metals play a very important role in our daily life. Therefore, let us study metals in greater detail.

To begin with, let us compare some of the important physical properties of metals with those of non-metals about which we have already learnt.

PHYSICAL PROPERTIES

Metals

(I)

1. All metals are solid except mercury which is a liquid.
2. Most of the metals are hard except sodium

Non-metals

(II)

Non-metals exist in all three states—hydrogen, nitrogen and oxygen are gases; bromine is a liquid and carbon, sulphur and phosphorus are solid.

Some non-metals, which are solid, are as soft

and potassium which can be cut with a knife.

3. Most of the metals have high melting and boiling points.
4. Metals are good conductors of heat and electricity—copper and aluminium are used for making electric wires.
5. Metals possess metallic lustre.
6. Metals can be beaten into sheets. Foils of some metals, e.g., aluminium, silver and gold are extensively used. This property is called malleability.
7. Most of the metals are ductile. They can be drawn into thin unbroken wires.

as sulphur and phosphorus whereas some are hard like diamond which is the hardest known substance.

The melting and boiling points of non-metals are comparatively low.

The non-metals do not conduct electricity. However, graphite (an allotrope of carbon) is used for making electrodes as it is a good conductor of electricity.

The non-metals are non-lustrous, except iodine, whose crystals are lustrous.

The non-metals are not malleable.

The non-metals are not ductile.

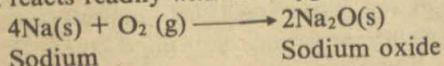
It is clearly seen from this comparative study of the physical properties of metals and non-metals that there is a significant difference in their properties. Actually, these differences in the properties of the metals and the properties of non-metals are due to the different structures of the atoms of these elements.

We have already studied the chemical properties of non-metals. We know that the number of electrons present in the outermost shell of the atom of an element influences the chemical behaviour of that element. Let us now study some general chemical properties of the metals.

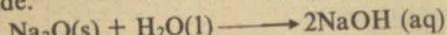
CHEMICAL PROPERTIES

1. Action of oxygen on metals

Some metals react with oxygen at room temperature whereas others react only on heating. Sodium reacts readily with the oxygen of air forming sodium oxide.



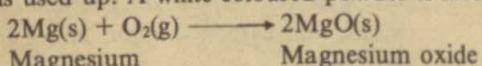
Sodium oxide immediately reacts with the moisture in the atmosphere to form sodium hydroxide.



A burning piece of magnesium ribbon continues to burn in air.

Experiment 9.1

Hold a burning piece of magnesium ribbon with a pair of tongs and introduce it into a gas-jar. The piece of magnesium continues to burn for some time until all the oxygen (of air) inside the gas-jar is used up. A white coloured powder is formed which is magnesium oxide.



At room temperature, dry air does not affect magnesium but moist air affects its surface when

exposed for some time.

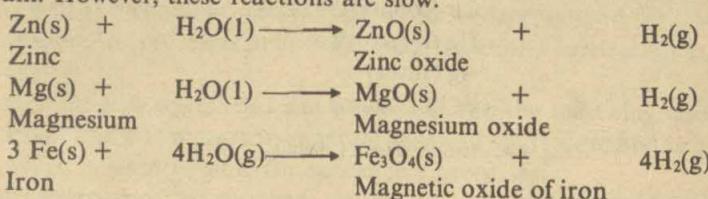
Copper and iron react with dry air after prolonged heating, forming the oxides. However, these metals do not burn in air.

2. Action of water on metals

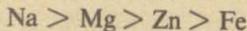
Many metals react with water under different conditions.

Sodium reacts with water violently. Sodium hydroxide is formed and hydrogen gas is evolved. The hydrogen evolved in this reaction can be collected and tested. The solution so formed can be tested for alkalinity by using a strip of red litmus paper which turns blue. The solution is alkaline due to sodium hydroxide. Potassium and calcium react with cold water in a similar manner.

Magnesium and zinc liberate hydrogen on reacting with boiling water whereas iron reacts with steam. However, these reactions are slow:



It is seen from the above and some other observations that the reactivities of sodium, zinc, magnesium and iron towards water are in the following order:



Aluminium reacts with cold water only if the protective coating of aluminium oxide over its surface is removed.

3. Action of dilute acids on metals

Dilute solutions of acids such as hydrochloric acid, sulphuric acid and nitric acid react differently with different metals.

Zinc liberates hydrogen gas from dilute acids more readily compared to lead.

Experiment 9.2

Place a piece of zinc in a dry test tube. Add a few ml of dilute hydrochloric acid to the test tube and close its mouth with a rubber stopper fitted with a delivery tube. Collect the evolved gas in a gas-jar by downward displacement of water. Test this gas for hydrogen.

Repeat this experiment with some other metals such as magnesium, aluminium, lead and iron. Metals like silver and gold do not react with dilute solutions of acids.

Metals have been arranged in the order of their decreasing activity on the basis of observations made during several experiments. This is known as activity series of metals (Fig. 9.1).

Hydrogen is not a metal but it has been assigned a place in the activity series of metals because it forms +ve ions (cations) like metals.

It is clearly seen from a perusal of the activity series that those metals which are placed above hydrogen in the series react with dilute solutions of acids liberating hydrogen. Those metals which are placed below hydrogen do not react with dilute acids.

K (potassium)
 Na (sodium)
 Ba (barium)
 Ca (calcium)
 Mg (magnesium)
 Al (aluminium)
 Zn (zinc)
 Fe (iron)
 Ni (nickel)
 Sn (tin)
 Pb (lead)
 H (hydrogen)
 Cu (copper)
 Hg (mercury)
 Ag (silver)
 Pt (platinum)

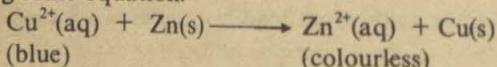
Fig. 9.1. Activity series of metals

4. Action of salt solutions on metals

Many metals displace the other metals from their salt solutions. This happens when a piece of the metal is kept immersed in the salt solution for some time.

Experiment 9.3

Take copper (II) sulphate solution in a beaker. Introduce a zinc rod into the beaker and allow it to stand. After a few hours, take out the rod from the salt solution, wash it and observe the colour of the rod. Copper is deposited on the zinc rod. This reaction can be represented by the following ionic equation:

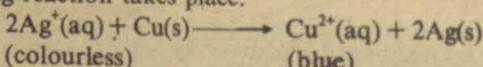


Copper deposited on the rod can be recovered by scraping it.

Similarly, silver is deposited on a strip of copper if the latter is kept immersed in a solution of silver nitrate for some time.

Experiment 9.4

Take silver nitrate solution in a beaker. Introduce a copper spiral into the solution and allow it to stand overnight. Silver is deposited on copper and the solution becomes blue in colour. The following reaction takes place:



The results of the experiments described so far clearly show that metal atoms become less reactive (i.e., more stable) down the activity series.

Having learnt about the general properties of metals, let us now study about some general methods of their extraction and refining.

Metals are obtained from their ores by applying certain processes which are known as general metallurgical processes. Let us study about the general metallurgy of metals.

9.2 General metallurgy

Some metals, like the less reactive metals, silver, gold, and platinum, are found mostly in the free or native state. Other metals are found in nature in combined states. Copper is found both in the free and combined states. The natural materials in which metals or their compounds occur in the earth are called minerals. Those minerals from which the metals are produced profitably are called *mineral ores*. A large percentage of rocky material, called gangue or matrix, is found along with metals and their ores.

Some of the important classes of ores used in the extraction of metals are—oxide ores, sulphide ores, carbonate ores and halide ores. In order to produce the metal from ores, several physical as well as chemical processes are used. These depend upon the nature of the ore and the local conditions. The processes involved in the production of a metal are collectively referred to as metallurgy.

The metallurgical operations can be divided into the following three stages:

- (i) Preliminary treatment to separate gangue from the ore and to convert it into a form which is more suitable for subsequent processes;
- (ii) Conversion of the enriched ore into metal by appropriate chemical reactions; and
- (iii) Refining of the metal to obtain it in a pure form.

A summary of these processes is given in the following chart:

An Outline of Main Metallurgical Operations

Ore



Preliminary treatment involving one or more of the following processes to remove gangue (rocky material, etc.) and to prepare the ore for further processing:

(i) Magnetic separation	(ii) Hydraulic washing
(iii) Froth floatation	(iv) Calcination
	(v) Roasting



Enriched ore containing higher concentration of the metal in a more readily extractable form

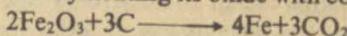


Wet process

Dry process

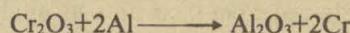
Leaching of the ore with a suitable reagent to extract metal in the form of a soluble salt, e.g., (i) Copper sulphide ores leached with dilute H_2SO_4 in the presence of atmospheric oxygen to give $CuSO_4$ solution. (ii) Extraction of uranium with H_2SO_4 as uranyl sulphate. These salts

Metals are obtained by using different reduction processes, e.g., (i) Iron is obtained by heating its oxide with coke.

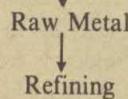


(ii) Chromium is obtained by reduction of its oxide with aluminium (Aluminothermite process)

may be used as such or converted into free metals.



(iii) Electrolytic reduction process is used for obtaining aluminium.



The metal obtained above is purified by one of the following methods:

- Electrolytic refining as in the case of copper and aluminium.
- Distillation or sublimation as in the case of mercury and zinc, respectively.
- Removal of impurities by oxidation as in the removal of carbon, phosphorus, silicon, etc., from pure metal.

Preliminary steps in metallurgy

The ore is crushed and ground. The gangue is separated from the metal compound by making use of differences in their physical properties. For example, some minerals may be attracted towards magnetic fields (magnetic separation) but gangue is not. This is the principle underlying the separation of Chromite (an ore of chromium) or Pyrolusite (MnO_2) from the gangue. In other cases, like the ores of tin and lead, advantage is taken of the differences in density. The lighter gangue particles are washed away in stream of water while the heavier minerals stay behind (hydraulic washing). Some of the sulphide ores have the property of adhering to air bubbles. These can be enriched by the froth floatation process. The powdered ore is mixed with water and pine oil and air is bubbled through it. The sulphide minerals float on the surface while the froth with gangue settle at the bottom. Volatile matter, like moisture of water or crystallisation, may be removed by simple heating (calcining). Most sulphide ores are heated in a stream of air to convert them to oxides and to remove sulphur as sulphur dioxide (roasting).

The enriched ore is converted into free metal through a series of chemical reactions.

Refining of metals

The metal obtained in the above step is generally not very pure and another treatment is required to purify it. For example, iron obtained from Fe_2O_3 (pig iron) contains a lot of carbon, silicon, phosphorus and some other impurities. These are removed by passing air through molten iron. The impurities are converted into their oxides and removed (oxidative refining). The more volatile metals like mercury and zinc are purified by distillation or sublimation. Impure copper is refined by electrolysis. The block of impure copper dipping in a solution of copper sulphate serves as the anode. The cathode is made of a thick plate of pure copper. On passing electric current, copper is dissolved from the anode and deposited on the cathode. The impurities collect at the bottom below the anode (electrolytic refining).

9.3 Sodium

Symbol – Na

Atomic mass – 23.0
Atomic number – 11

Place in the periodic table

The electronic arrangement in sodium is 2, 8, 1. The outermost shell of an atom of sodium contains only one electron. It is placed in Group I of the periodic table along with lithium and potassium.

Occurrence

Sodium chloride, a very common compound of sodium, is known to exist since ancient times. It is found in abundance in sea water. In 1807, Humphry Davy obtained sodium by the electrolytic dissociation of sodium hydroxide.

Sodium is a highly reactive substance. It does not exist in its native state. Some of the common naturally occurring salts of sodium are common salt (sodium chloride), Chilli saltpetre or caliche (sodium nitrate), sodium carbonate and borax.

Sodium is obtained on commercial scale by electrolytic dissociation of molten sodium chloride or sodium hydroxide. In both of these methods, sodium is deposited at the cathode.

Uses of sodium

- (i) It is used as an important chemical reagent in organic reactions.
- (ii) Sodium amalgam (sodium + mercury) is used as a reducing agent.
- (iii) It is used for making a large number of useful compounds.
- (iv) It is used in sodium vapour lamps which are used for street lighting.

9.4 Calcium

Symbol – Ca

Atomic mass – 40.1
Atomic number – 20

Place in the periodic table

The electronic arrangement in calcium is 2, 8, 8, 2. The outermost shell of an atom of calcium contains two electrons. It is, therefore, placed in Group II of the periodic table along with some other elements such as beryllium, magnesium, strontium and barium.

Occurrence

Calcium is a highly reactive element. Therefore, it does not exist in nature in a free state. It occurs as marble, limestone and dolomite (all carbonates); as gypsum (calcium sulphate); as fluorspar (a fluoride) and as phosphorite (a phosphate).

Most of the plants and animals require calcium for their growth. Sea-water contains some calcium salts in dissolved state. Shells of many animals are made of calcium carbonate. Shell of an egg is made of calcium carbonate. A genuine pearl is calcium carbonate. Bones, teeth and horns are made of calcium phosphate.

Calcium is obtained by electrolytic dissociation of a mixture of calcium chloride and calcium fluoride.

Uses of calcium

- (i) It is used for removing last traces of moisture from alcohol because it absorbs water.
- (ii) It is used for removing last traces of air from inert gases.
- (iii) Its compounds are recommended for use during teething period in children and also to expecting women.
- (iv) Substances containing calcium, e.g., limestone and gypsum are used for manufacturing cement and mortar.
- (v) Slaked lime, which is used for white washing, is also a disinfectant.

9.5 Aluminium

Symbol – Al

Atomic mass – 27.0

Atomic number – 13

Place in the periodic table

The electronic arrangement in aluminium is 2, 8, 3. The outermost shell in an atom of aluminium contains three electrons. It is, therefore, placed in Group III of the periodic table.

Occurrence

Aluminium was discovered by Oersted in 1825. It was obtained in 1886 by electrolytic dissociation of a substance known as cryolite. Aluminium does not occur in a free state. The earth's crust contains a fairly good percentage of the compounds of aluminium such as bauxite ($Al_2O_3 \cdot 2H_2O$), cryolite (Na_3AlF_6), felspar, mica, kaolin, slate and alumstone.

In India, the chief source of aluminium is bauxite. The bauxite ore is first purified and then converted into alumina, Al_2O_3 . A mixture of alumina and purified cryolite is then subjected to electrolytic dissociation in a specially designed tank. Cryolite acts as a flux in the mixture and reduces its melting point.

Aluminium obtained by this method is impure. Therefore, it is further purified by electrolytic refining process.

Uses of aluminium

- (i) Being a light metal, it is used for building the bodies of aeroplanes and motor engines. It is also used for making utensils, photo frames, and many other items of household use.
- (ii) It is a good conductor of electricity. Therefore, transmission wires are made of aluminium now-a-days.
- (iii) Aluminium foils are made for packing foodstuffs and medicines.
- (iv) Aluminium powder is used for making silver paint.
- (v) Aluminium powder is used in aluminothermy. This process is used in joining broken pieces of iron rails and machine parts.

In this process, a mixture of aluminium powder and iron (III) oxide, having a ratio of 1:3 (known as thermite), is taken in a crucible with a hole at the bottom. The crucible is placed over the broken pieces of the iron rails placed near each other. For starting the reaction, a piece of magnesium ribbon is set on fire. This ribbon leads the fire to an ignition mixture (a mixture of aluminium powder and barium peroxide) which is placed over the thermite. The ignition mixture catches fire. A large amount of heat is evolved which ignites the thermite. The reaction is also very highly exothermic (Fig. 9.2). As a result of the intense heat that is produced, the iron formed by the reaction of aluminium powder and iron (III) oxide melts and is allowed to drop over the gap between the broken pieces which are kept hot. The space is thus filled with molten iron and the broken pieces of rails are joined together.

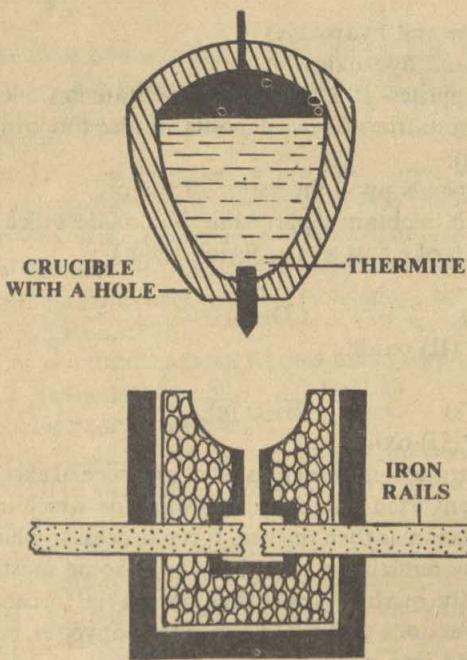


Fig. 9.2. Welding by aluminothermy

(x) Ships are made of alloys of aluminium because of the latter being resistant to sea-water.

(vi) Some alloys of aluminium e.g., duralumin and magnalium, are very useful in making utensils and many other articles which are used in daily life. The percentage compositions of these alloys are as follows:

(a) Duralumin — 95.0% Al, 4.0% Cu, 0.5% Mg and 0.5% Mn.
 (b) Magnalium — 5.3% Mg, 94.70% Al.

(vii) Magnets used for doing some very common experiments in laboratories are made of an alloy known as alnico (chief constituents: aluminium, nickel and cobalt).

(viii) Alloys of aluminium are used for making the bodies of aircrafts.
 (ix) Objects made of anodized (coating of a thin protective layer or film on a metal surface by electrolytic methods) aluminium can absorb dyes giving a bright coloured surface to the metal.

9.6 Copper

Symbol — Cu

Atomic mass — 63.5
 Atomic number — 29

The electronic arrangement in copper is 2, 8, 18, 1. The outermost shell in an atom of copper contains one electron. It is one of the transition elements. Therefore, it has been placed with other transition elements in the periodic table. There is no similarity in the properties of copper with the elements sodium, potassium and lithium although their atoms contain only one electron in their outermost shells and all of them form basic oxides on combining with oxygen.

Occurrence

Copper has been known since ancient times. Ancient man used this metal to make utensils and many other articles of day to day use.

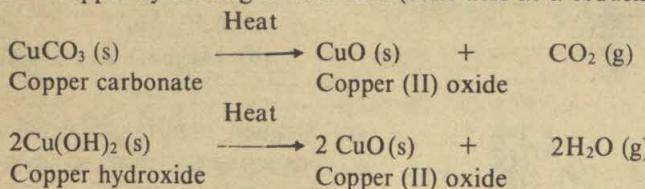
In the earth's crust, copper is found in the following ores:

- (i) Copper pyrites (a sulphide)
- (ii) Copper glance (a sulphide)
- (iii) Malachite (a mixture of carbonate and hydroxide)
- (iv) Azurite (a mixture of carbonate and hydroxide)

The main source of copper is copper pyrites. It is found in native state in Chile, China, Mexico, U.S.A., U.S.S.R. and some other countries. Its rich deposits are also found in India at Singhbhum (Bihar) and Khetri (Rajasthan).

Extraction of copper from its ores depends upon the nature of the ore.

Carbonate ores are strongly heated in air to obtain copper oxide. The oxide is then reduced to metallic copper by heating it with coke (coke acts as a reducing agent).



Sulphide ores are first crushed, concentrated and then roasted in presence of excess of air. Copper pyrites (copper (II) sulphide) is converted into copper (I) sulphide which in turn is converted to copper (I) oxide. The entire mixture is then smelted. It is a process in which metal is obtained from calcined or roasted ore by reducing it with the help of some substances in a molten state in a special furnace. Finally, the mixture is put in another special furnace known as Bessemer converter. As a result of the reactions that take place in the converter, copper (I) sulphide and copper (I) oxide are converted into metallic copper. This process is known as Bessemerization.

Pure copper is obtained by electrolytic refining of the impure metal in an electrolysing tank. In this tank, the cathode is made of pure copper strips whereas thick sheets of impure copper act as anode. The electrolyte used is acidified copper sulphate solution. At the end of the process, copper is obtained as a thick deposit on the cathode.

Uses of copper

- (i) It is used for making electrical appliances and wires as it is a good conductor of electricity.
- (ii) It is alloyed with some other metals for making coins.
- (iii) It is used for electroplating.

- (iv) It is used for making calorimeters and vacuum pans.
- (v) It is now-a-days being extensively used for making printed electronic circuits.
- (vi) It is used for making some very important alloys such as brass, bronze, German silver, bell metal and gun metal.

The composition of brass and bronze are as follows:

Brass — Cu 60 — 90% Zn 40 — 10%

Bronze — Cu 88 — 96% Sn(tin) 12 — 4%

These alloys are used for making a large number of articles, e.g., utensils, flower vases, lamp shades and other decoration articles.

9.7 Zinc

Symbol — Zn

Atomic mass — 65.4

Atomic number — 30

The electronic arrangement in zinc is 2, 8, 18, 2. The outermost shell in an atom of zinc contains two electrons. In the periodic table, it has been placed among the transition elements.

Occurrence

Like copper, zinc has also been known since early times. Archaeological excavations have shown that ancient man used utensils and many other articles made of an alloy of zinc and copper. Zinc is not found in a free state in nature. In a combined state, it is mainly found in the form of zinc blende (a sulphide; ZnS) and calamine (a carbonate; ZnCO₃).

In India, zinc ores (chiefly zinc blende) are being mined from Zawar mines located near Udaipur in Rajasthan.

Zinc is extracted from its ores mainly by two methods:

- (i) Reduction by coke
- (ii) Electrolytic process.

In the first method, the ore, mainly zinc blende, is crushed, concentrated and then roasted at 900° C. The sulphide is thus converted into oxide and sulphate of zinc. The latter decomposes into the oxide at the above-mentioned temperature. The roasted ore, consisting mainly of zinc oxide, is reduced by coke to obtain zinc.

Zinc obtained by this process is impure. It is purified by a process known as electrolytic refining. A plate of pure zinc acts as cathode and the impure zinc acts as anode during electrolytic refining.

In the electrolytic process, zinc sulphate obtained by roasting the ore is electrolysed in a cell in which lead acts as the anode and aluminium acts as the cathode. When an electric current is passed through the cell, pure zinc is deposited over the cathode. It is then removed by scrapping.

Uses of zinc

- (i) It is used for galvanising of iron. (The process of depositing a layer of zinc on the objects made of iron is known as galvanisation. It is done either by electroplating zinc on the surface of iron or by immersing the object made of iron in a bath containing molten zinc).
- (ii) It is used for making containers of dry cells.
- (iii) It is used as a reducing agent in a large number of chemical reactions.

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- (iv) It is used for making a large number of alloys, e.g., brass, German silver, etc.
- (v) Compounds of zinc are used for a variety of purposes, e.g., for manufacturing paints, elastoplast (an antiseptic), preservatives for leather, mordants (substances which help in fixing the dyes over the surface of textiles), etc.
- (vi) Compounds of zinc (calamine, $ZnCO_3$) are used for making cosmetics, especially face creams.

9.8 Iron

Symbol – Fe

Atomic mass – 55.9

Atomic number – 26

The electronic arrangement in iron is 2, 8, 14, 2. The outermost shell in an atom of iron contains two electrons. It has been placed in the periodic table along with some important transition metals such as nickel and cobalt. There are many similarities in the properties of these metals with iron.

Occurrence

Iron is rarely found in its native state. In the combined state, it is found in the form of haematite, limonite, magnetite and iron pyrites. The first three of these substances are ores of iron from which it is profitably extracted.

In India, iron ores are found chiefly in the States of Bihar, West Bengal and Karnataka. The chief iron producing factories in India are located at Asansol, Jamshedpur, Bhilai, Durgapur, Rourkela and Bhadravathi. In ancient India, people knew how to extract iron from its ores and were experts in producing steel. The iron pillar near Qutab Minar in Delhi is a glaring example of the knowledge of the art of making steel in ancient India.

Three different forms of iron are mainly produced in the factories. These are:

- (i) Pig iron or cast iron
- (ii) Wrought iron
- (iii) Steel.

The properties of the above-mentioned types of iron are different because of a difference in their carbon-content. Steel is one of the strongest and most important forms of iron. All forms of steel usually contain some manganese, also. Some important forms of steel are:

- (a) Mild steel—This type of steel is hard and elastic. Its carbon-content is very low.
- (b) Hard steel—It is normally prepared by immersing red hot mild steel in water. Its carbon-content is slightly higher.
- (c) Alloy steels—These are obtained by adding metals like nickel, cobalt, chromium, etc., in different proportions, to steel.

With 10-12% chromium, iron forms a very well known alloy steel called stainless steel.

Uses of iron

Iron is used for a variety of purposes because of its characteristic properties. You are already familiar with the use of iron in our daily life.

Iron finds its use mostly in the following forms:

- I. **Cast iron:** It is an impure form of iron. The impurities are carbon (4%) with smaller quantities of some other substances such as silicon, phosphorus and sulphur. Cast iron is brittle

and has a low melting point. Therefore, it is used for making bases for Bunsen burners, hot water plates, railings and fire-grates. It can not be welded.

II. *Wrought iron*: It is almost pure form of iron. Its melting point is higher than cast iron. It is malleable and therefore can be hammered, forged, and welded when hot. It is used for making horse-shoes, iron nails and agricultural implements. However, now-a-days wrought iron is being replaced by mild steel as the latter is cheaper to produce.

III. *Steel*: Steel is composed of iron and a small proportion of carbon. It also contains some other substances which are added to it depending on the usage to which it is put. Steel of varying degrees of hardness are produced by reheating the steel to carefully regulated temperature. This process is known as 'tempering'.

Different kinds of carbon steels and alloy steels are used for making different articles, e.g., propeller shafts for ships, parts of aeroplane engines, armour plates, cutting tools, springs, axles, motor car frames, stone crushing machines, rails, iron safes, fire-resistant safes, measuring instruments, pendulums for clocks, cycle and engine parts, cooking utensils, buckets, etc.

Rusting of iron

Rusting of iron is a very common phenomenon. You have seen rusted iron nails and pipes. When a piece of iron is left exposed to moist air, it is found covered with a reddish-brown coating which can easily be scrapped from its surface.

Experiment 9.5

Take a few iron nails or pieces of iron. Rub them with sand paper or a triangular file. Take them in a test tube and pour some ordinary water into it. Allow the test tube to stand. Take out the iron nails/ pieces after a few days, dry them in air and observe.

A reddish-brown coating is formed on the surface of the metal. This coating is detached from the surface by scraping. It is rust.

The process of formation of rust is called rusting. This process is similar to burning. Whereas the latter is a fast reaction, rusting is a slow process. During rusting, a small amount of heat is slowly evolved. Rusting also causes a gain in mass.

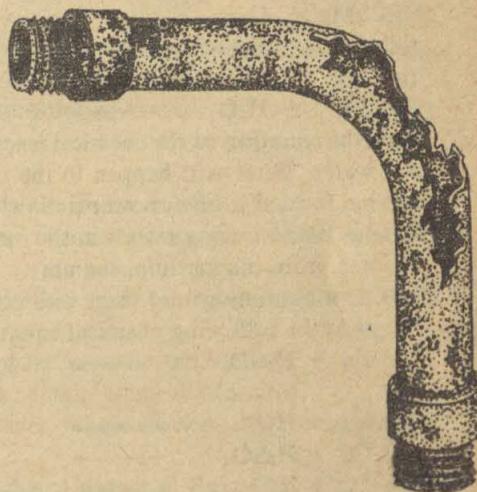


Fig. 9.3 Rusting of iron.

Rust is a mixture of iron (III) hydroxide, Fe(OH)_3 and iron (III) oxide, Fe_2O_3 , and is formed by the action of water on iron in presence of dissolved oxygen and sometimes carbon dioxide also.

Protection of iron against rusting

There are several methods for preventing the rusting of iron. You are already familiar with them. Some simple methods are as follows:

- (i) By covering the surface with grease, paints, enamels and lacquers.
- (ii) By covering the surface with coating of some metals, e.g., tin, nickel, chromium, aluminium and zinc. These metals are coated over iron-surface by electroplating or any other method.

There are some other methods also for protecting iron from rusting. These methods include coating of oxide and phosphate of iron over the objects made of iron.

Exercises

1. Name five metals which are used in our day to day life.
2. Name five metals which are used in industrial processes.
3. List five differences in the physical properties of metals and non-metals.
4. What do you understand by ductility and malleability of a metal? Give examples of two metals which are both ductile and malleable.
5. Name two metals which are good conductors of both heat and electricity.
6. Complete the following chemical equations:
 - (i) $\text{Na} + \text{O}_2 \longrightarrow$ _____
 - $\text{Na}_2\text{O} + \text{H}_2\text{O} \longrightarrow$ _____
 - (ii) $2\text{Mg} + \text{O}_2 \longrightarrow$ _____
 - (iii) $\text{Zn} + \text{H}_2\text{O} \longrightarrow$ _____
 - (iv) $\text{Mg} + \text{H}_2\text{O} \longrightarrow$ _____
 - (iv) $\text{Fe} + \text{H}_2\text{O} \longrightarrow$ _____
7. Write the equation of the chemical reaction that takes place when a piece of sodium is put over water. What will happen to the colour of a red litmus paper if it is dipped in the solution formed in the above reaction?
8. Arrange the following metals in the increasing order of their reactivities towards water: zinc, iron, magnesium, sodium
9. Why does aluminium not react with cold water under ordinary conditions?
10. Complete the following chemical equations:
 - (i) $\text{Zn} + \text{H}_2\text{SO}_4 \longrightarrow$ _____
(dilute)
 - (ii) $\text{Na} + \text{HCl} \longrightarrow$ _____
 - (iii) $\text{Cu} + \text{H}_2\text{SO}_4 \longrightarrow$ _____
 - (iv) $\text{Mg} + \text{HCl} \longrightarrow$ _____
 - (v) $\text{Al} + \text{HCl} \longrightarrow$ _____
11. What will happen if a strip of zinc is kept immersed in a solution of copper sulphate for some time? Write the ionic equation of the reaction that takes place.
12. What will happen if a strip of copper is kept immersed in a solution of silver nitrate for some time? Write the ionic equation of the reaction that takes place.
13. Name three metals which occur in the native state.

14. Name three types of ores from which metals are extracted.
15. Complete the following sentences:
 - (i) The processes involved in the production of a metal from its ores are collectively known as _____.
 - (ii) The rocky material found with ores is known as _____.
 - (iii) The process in which the lighter gangue particles are washed away in a stream of water while the heavier minerals stay behind is known as _____.
 - (iv) The method of removing volatile matter from ores is known as _____.
 - (v) Roasting is a process in which _____.
16. Describe briefly the general metallurgical operations.
17. Describe briefly how impure copper is refined.
18. Write the electronic arrangement in sodium. Name two other elements which have been placed along with sodium in the same group in the periodic table.
19. Name one source in which sodium chloride is found in abundance.
20. Which element is obtained if sodium hydroxide is subjected to electrolytic dissociation?
21. Why is sodium not found in its native state?
22. Name four naturally occurring substances which contain sodium. Write their chemical formulae also.
23. Why is sodium deposited at the cathode during electrolytic dissociation of molten sodium chloride or sodium hydroxide?
24. State any three uses of sodium.
25. Write the chemical formulae of sodium carbonate and sodium bicarbonate.
26. Write the electronic arrangement in calcium.
27. Name two elements which are placed in the same group in the periodic table as calcium.
28. Name any five naturally occurring substances which contain calcium.
29. Which element is obtained by the electrolytic dissociation of a mixture of calcium chloride and calcium fluoride?
30. State five uses of compounds of calcium.
31. Why is calcium used for removing traces of moisture from alcohol?
32. Write the chemical formulae of calcium oxide, calcium hydroxide, calcium chloride, calcium carbonate and calcium bicarbonate.
33. Write the electronic arrangement in aluminium. How many neutrons does an atom of aluminium contain?
34. Why has aluminium been placed in Group III of the periodic table?
35. Name five naturally occurring substances which contain aluminium.
36. Explain in brief how copper is extracted from its ores. Where are deposits of copper found in India? Mention any four uses of copper.
37. Name the ore mined from Zawar mines located near Udaipur in Rajasthan. Explain the principles that form the basis of extracting the metal from this ore.
38. State five uses of zinc.
39. Name the three different types of iron that are mainly produced in the factories. In what respects do they differ from one another? State briefly their uses.
40. Describe an experiment to demonstrate the process of rusting. How is iron protected against rusting?

UNIT 10

Carbon and its Compounds

Symbol — C

Electronic

arrangement — 2, 4

Atomic mass — 12

Atomic number — 6

Carbon is the most widely distributed element in nature. Its existence has been known since very early times in such forms as charcoal, coal, graphite and diamond. It was in 1775, however, that Lavoisier proved the chemical identity of diamond and charcoal by burning them separately. Both produced the same substance namely, carbon dioxide.

The outermost shell of carbon atom contains four electrons, and therefore carbon is placed in Group IV of the periodic table. Carbon is unique since it can combine with itself. Further, one carbon atom combines with another carbon atom to form a covalent bond, which being strong, does not break easily. Therefore, carbon is less reactive than other elements such as oxygen, sulphur and chlorine.

10.1 ALLOTROPY OF CARBON

In Class IX, you have studied about the allotropy of oxygen. Allotropy is exhibited by the element carbon, as well. It exists in two forms, namely, crystalline and amorphous. The crystalline forms are diamond and graphite. Amorphous forms, like coal, charcoal and lamp black, are found on minute observation, to be really made up of small crystals of graphite.

10.1.1 Diamond

Diamond is the purest form of carbon. It is the hardest substance known. Each carbon atom in diamond is attached to four other carbon atoms through four strong covalent bonds (Fig. 10.1). That is why diamond is such a hard substance. It is because of this hardness that diamond is used for making glass cutters and rock borers for drilling. Diamond is also a non-conductor of

heat and electricity.

Another important property of diamond is its high refractive index (2.5) that makes it useful as a precious gem for making jewellery. When diamond is cut and polished, brilliant light is refracted by its surfaces.

10.1.2 Graphite

Graphite is a black and soft crystalline substance. It occurs in nature; and also manufactured artificially by heating coke to about 3000°C in an electric furnace.

Graphite possesses a metallic lustre and soapy touch. It is a good conductor of heat and electricity. This is because of the peculiar arrangement of carbon atoms in the crystals of graphite (Fig. 10.2).

Graphite marks paper black and is, therefore, known as black lead. Mixed with desired quantities of wax or clay, graphite is used for making 'lead pencils'. It is also used as a lubricant in heavy industry and for making electrodes.

10.1.3 Amorphous carbon

Animal charcoal, wood charcoal, lamp black and sugar charcoal are amorphous forms of carbon. The animal charcoal is obtained by heating animal bones in a limited supply of air. Therefore, it contains calcium phosphate. It is very useful in removing colouring matter from

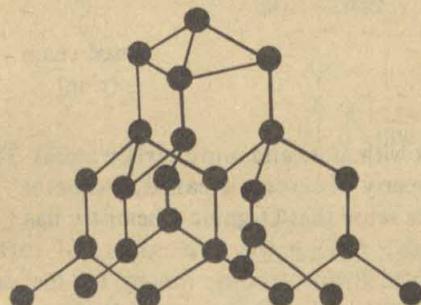


Fig. 10.1 Structure of diamond

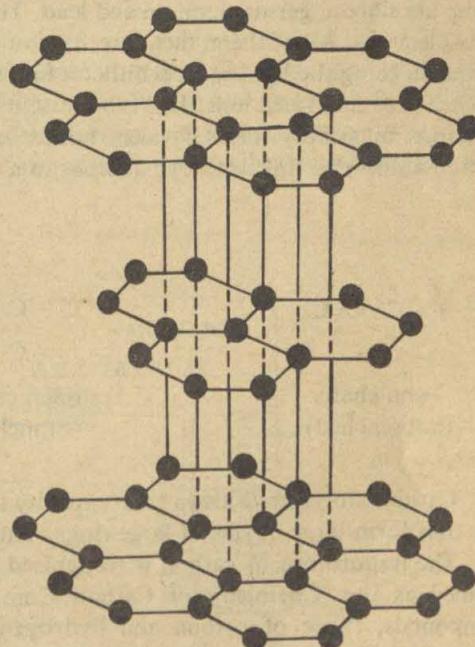
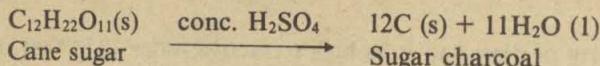


Fig. 10.2 Structure of graphite

sugar-cane juice in industry and from impure organic compounds in laboratory. Wood charcoal is obtained by heating wood in a limited supply of air. It is porous and therefore used as absorbent for gases. Lamp black is obtained by burning oils in a limited supply of air. It is used for making black shoe-polish, printer's ink and black paints. A very pure form of amorphous carbon is sugar charcoal. It is obtained by the action of concentrated sulphuric acid on cane sugar.

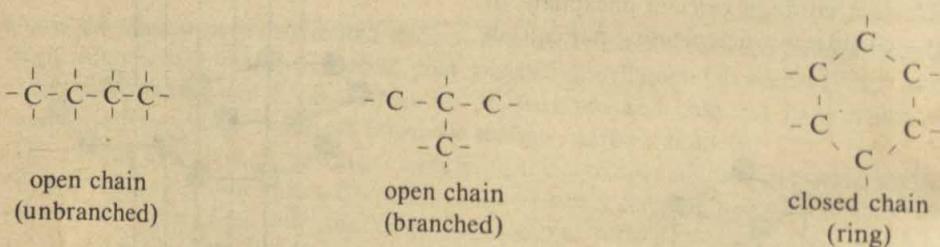


All the allotropic forms of carbon burn at different temperatures in excess oxygen to form carbon dioxide, CO_2 . The purest forms, such as diamond and sugar charcoal, produce only CO_2 on complete combustion. This shows that all the above forms are allotropes of carbon.

10.2 TETRAVALENCY OF CARBON AND FORMATION OF A LARGE NUMBER OF CARBON COMPOUNDS

Among 106 elements carbon is extra-ordinary in many respects. For example, the number of carbon compounds is relatively very large. While carbon is known to form about 600,000 compounds, the number of compounds formed by rest of the elements is only 30,000. Let us see what is unique about the nature of carbon atom that enables it to make such a vast variety of compounds and in such a large number.

Carbon is the first member of Group IV of the periodic table. The other elements of this group are silicon, germanium, tin and lead. There are four electrons in the valence shell of all these elements. All of them, therefore, exhibit a valency of four. Among these, carbon atom is unique in being the lightest. It is difficult for carbon either to lose or gain four electrons in the valence shell and form ions. This is because it would need a large amount of energy. Carbon, therefore, invariably forms covalent bonds in their compounds. Through covalent bonding carbon atoms can link with one another in a variety of ways as shown below:



Carbon atoms have also a great capacity to link with more and more carbon atoms. They can thus form large chains or large rings. This property of carbon is called *catenation*.

The importance of carbon is recognised in the sense that Organic Chemistry has been defined as the 'Chemistry of Carbon Compounds'. Among the vast variety of carbon compounds, those of carbon and hydrogen, named hydrocarbons, are by far the most important. Organic chemistry is, therefore, also defined as the 'Chemistry of Hydrocarbons and their derivatives'.

10.2.1 Sources of organic compounds

Organic compounds may be obtained from a variety of sources, such as micro-organisms, plants, animals and minerals. Among these sources plants provide us the maximum number of organic substances such as sugar, starch, cellulose, vegetable oils, essential oils, drugs, dyes, insecticides, alkaloids, etc.

Coal is the next important source for synthetic products. Thus, it is a rich source of benzene, toluene, phenol and naphthalene.

Another important source of organic compounds is mineral oil (petroleum). Some important products obtained from it are: petrol, kerosene, lubricating oil, vaseline and other petrochemicals.¹

A large number of organic compounds are also obtained by synthesis.

10.3 HYDROCARBONS

10.3.1 Methane—the simplest hydrocarbon

We can even predict the molecular formula of the simplest hydrocarbon. It would have at least one carbon atom. Being tetravalent this carbon atom would need four hydrogen atoms (monovalent) to satisfy the valencies of carbon. The molecular formula for the simplest hydrocarbon would thus be CH_4 . Compound of this molecular formula is in fact known, and called methane. Let us prepare methane and study its properties.

Experiment 10.1

Take about 2g each of sodium acetate and soda lime² in a hard glass boiling tube. Fit it with a cork along with a delivery tube as shown in Figure 10.3 Fix the boiling tube horizontally on a stand. Place a beaker of water so that the tip of the delivery tube is under water. Heat the boiling tube carefully and collect the evolved gas in several test tubes by downward displacement.

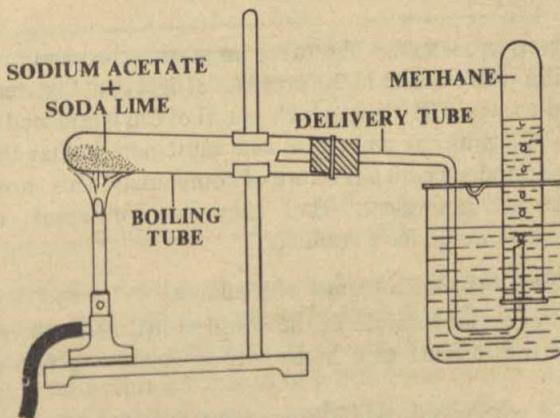
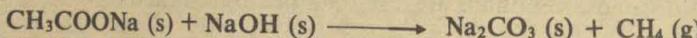


Fig. 10.3 Preparation of methane

1. A chemical which is obtained from petroleum or natural gas or is a derivative of a petroleum product, is known as a petrochemical.
2. Soda lime is a solid mixture of caustic soda and calcium oxide.

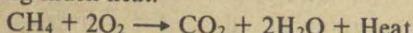
Observe if the gas has any colour and odour. Is the gas soluble in water, insoluble or partly soluble? How will you find this out? Now hold a lighted match-stick near the mouth of a test tube filled with the gas. What do you observe and what is your conclusion from this observation?

The reaction for the formation of methane is represented by the following chemical equation:



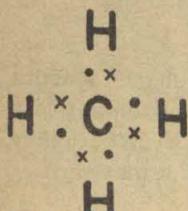
Sodium acetate (Taken as soda lime) Sodium carbonate Methane

Methane is a colourless, odourless and tasteless gas. It is almost half as heavy as air. It is insoluble in water. It burns in air with a bluish flame producing carbon dioxide and water, and also giving much heat.

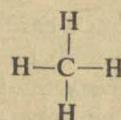


Methane is also known as 'marsh gas' because it is formed by the decomposition of plants lying at the bottom of stagnant water, in the absence of air.

The molecule of methane may be represented in a number of ways such as



Electronic formula



Structural formula



Molecular formula

Equivalence of hydrogens in methane: The most important chemical property of methane is that it undergoes reaction with chlorine in the presence of light or at high temperature to give one monosubstitution product, viz., CH_3Cl , in which one H of CH_4 is replaced by Cl (see page 171 of this Unit for details). A significant point that one must note is that this monosubstitution product is a single compound, and not a mixture of compounds. This shows that all hydrogens of methane molecule are equivalent. Had they been different, a mixture of four monosubstitution products would have resulted.

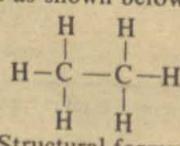
10.3.2 Homologous series—the homologues of methane

We could predict the molecular formula of the simplest hydrocarbon with only one carbon atom. Can we predict the formula of a hydrocarbon containing two carbon atoms in its molecule?

In the hydrocarbon with two carbon atoms in its molecule, the carbon atoms have to be linked directly since hydrogen is monovalent. This would leave six valencies of the two carbon atoms to be satisfied by six H atoms as shown below.



Molecular formula



Structural formula

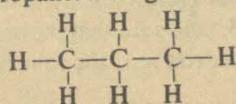


Condensed structural formula

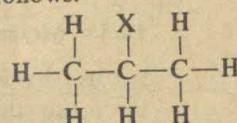
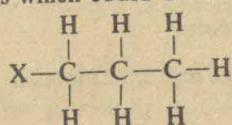
The hydrocarbon with formula C_2H_6 is known and named ethane. It can be prepared by a method similar to that used for methane.

Again, all six hydrogen atoms of ethane molecule are equivalent because it forms only one monosubstituted chloro compound, viz., ethyl chloride (C_2H_5Cl) by reaction with chlorine (see page 171).

Now let us examine a hydrocarbon containing three carbon atoms, i.e., C_3H_8 , which is called propane. Straight away you can now write the following structural formula:



Here, two hydrogens of the middle carbon atom are different from the remaining six hydrogens attached to terminal carbon atoms because it gives two monosubstitution products which could be written as follows:



This indicates that hydrogens attached to the same carbon atom are equivalent but those at different carbon atoms may be equivalent or non-equivalent.

Now you can yourself work out the structural formulae and equivalence of H for higher hydrocarbons. Some of these hydrocarbons are shown in Table 1.

TABLE I
Some Homologues of Methane

Name	Number of carbon atoms	Molecular formula	Molecular mass
Methane	1	CH_4	16
Ethane	2	C_2H_6	30
Propane	3	C_3H_8	44
Butane	4	C_4H_{10}	58
Pentane	5	C_5H_{12}	72

Like the members of a family, all these hydrocarbons bear much resemblance in their properties. There are small variations in physical properties, but the change from one member to the next is quite graded. The difference in molecular masses between any two adjacent members is 14 units (amu). This is because of a difference of one carbon and two hydrogen atoms ($-CH_2-$ group) in their respective molecular formulae. The regularly increasing molecular mass of successive members makes them more and more dense. Therefore density increases gradually and similarly boiling points of successive members gradually rise so that higher members are liquids (e.g., C_8H_{18}) or even solids (e.g., $C_{18}H_{38}$) at ordinary temperatures.

These hydrocarbons resemble in their chemical properties, e.g., all of them burn in oxygen to form carbon dioxide and water. It is possible to write a general molecular formula equally applicable to all members of the series, e.g., the general formula, C_nH_{2n+2} (wherein 'n' represents the number of carbon atoms) holds good for all the above hydrocarbons. Such a series of

organic compounds, in which members resemble closely in properties, can be represented by a general molecular formula and successive members differ by $-\text{CH}_2-$ group is known as *homologous series*. The homologous series of the above mentioned hydrocarbons is called 'open chain saturated hydrocarbons' or *alkanes*.

10.3.3 Three-dimensional representation of methane

The question whether all four hydrogens and carbon atom of methane are situated in the same plane (i.e., planar) or are in different planes (i.e., non-planar) comes immediately to our mind. An answer to this was given first by le Bel and Van't Hoff in 1873, who said that the molecule is three-dimensional. The carbon atom is at the centre of a tetrahedron and the four hydrogen atoms are located at its four corners, as shown in Fig. 10.4. Consequently each $\text{H} > \text{C} > \text{H}$ angle is $109^\circ 28'$.

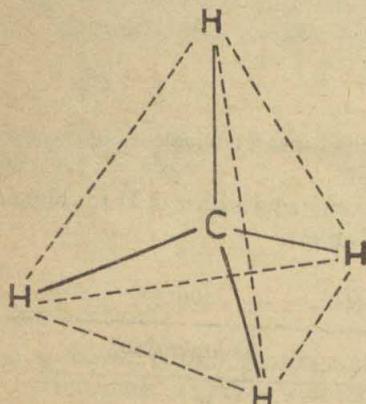


Fig. 10.4 Three-dimensional structure of methane

Model of ethane (C_2H_6): You may try two methods for making its molecular model.

- Link two carbon atoms through a spring which represents a single bond. Now link the six hydrogen atoms, one by one, to the two carbon atoms.

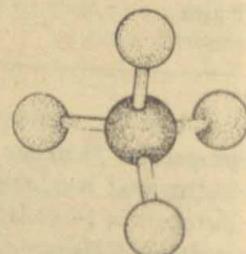


Fig. 10.5 Model of methane molecule

¹(a) Molecular models of different types are available in the market. The simplest one is Ball-stick type, wherein 'balls' are either of plastic or wooden, and represent atoms. The 'sticks' of the model are of either stick or spring, and represent the chemical bonds.

(b) In case you cannot procure a model, you can yourself improvise it using clay balls and match sticks.

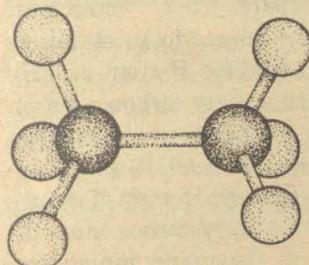
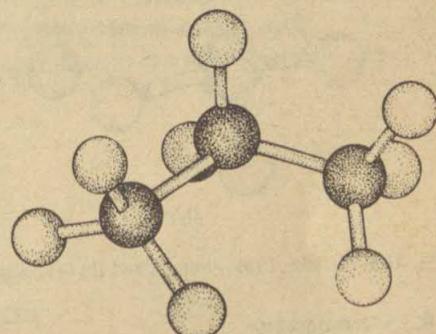
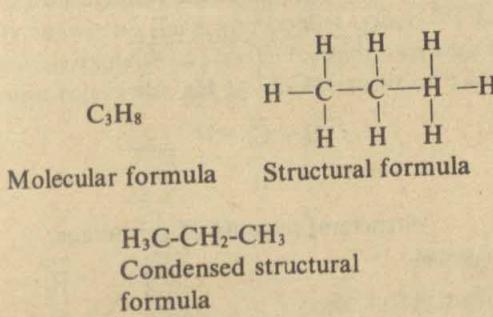


Fig. 10.6 Model of ethane molecule

Model of propane (C_3H_8): Now let us try to build a molecular model of propane from that of ethane by substituting one H atom by a $-CH_3$ group.

$\text{H}-\text{C}-\text{C}-\text{H} \xrightarrow[\text{replaced by } -\text{CH}_3 \text{ group}]{\text{one H atom}} \text{H}-\text{C}-\text{C}-\text{C}-\text{H}$

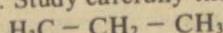
Ethane **Propane**



Three-dimensional model of propane

Fig. 10.7 Different representations of propane molecule

Model of butane (C_4H_{10}): We can now build the model of the next higher homologue (i.e., butane). Study carefully the structural formula of propane given below:



$\text{H}_3\text{C} - \text{CH}_2 - \text{CH}_3$
It is easy to see that the six H-atoms attached to the two-end-carbon atoms are equivalent, but are different from the two H-atoms attached to the middle carbon atom. Two end-carbon atoms are called primary carbon atoms and the middle carbon atom is called a secondary carbon atom.

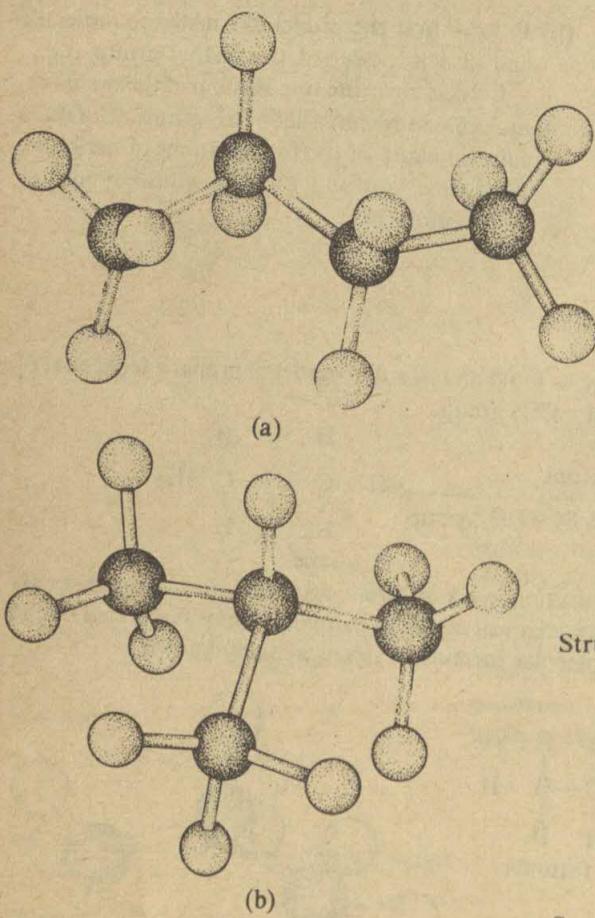


Fig. 10.8 Models of (a) *n*-butane and (b) *iso*-butane molecules.

10.3.5 Isomerism

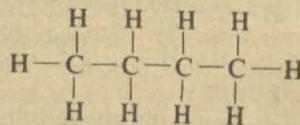
The two models or the two structural formulae represent two different compounds of the same molecular formula C_4H_{10} . They have different boiling points, densities, etc. The compounds are different because the arrangement of four carbon atoms and ten hydrogen atoms in their respective molecules is different. The two compounds are said to have different structures.

The compounds that have the same molecular formula but different structures (i.e., arrangement of atoms in the molecule), having different physical and chemical properties are called *isomers*. This phenomenon, in which different compounds exist with the same molecular formula but different structural formulae, is called *isomerism*, and is quite common in organic chemistry. *n*-Butane and *iso*-butane are examples of isomerism in which chains of carbon atoms differ. These isomers are called chain isomers and the phenomenon is called *chain isomerism*.

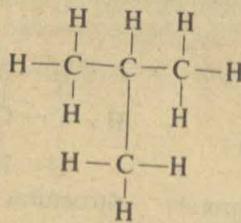
Prepare two molecular models of butane by substituting:

- One H-atom on primary carbon atom of propane molecule, with $-CH_3$ group.
- one H-atom of secondary carbon atom of propane molecule, with $-CH_3$ group.

Identify to which of the following structural formulae your models correspond:



Structural formula of *n*-butane



Structural formula of *iso*-butane

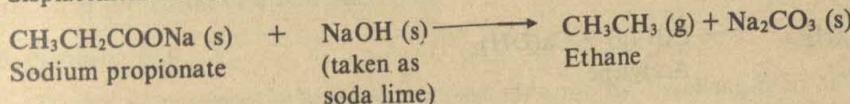
10.3.6 Ethane, ethylene and acetylene—preparation and properties

We know that the valency of carbon atom is four, and it can be represented by $-C-$. These four valencies of a carbon may all be satisfied with hydrogen atoms as in methane; or one valency be satisfied with carbon and the other three with H-atoms as in ethane (CH_3-CH_3). However, a carbon atom can also link with another by two valencies or three valencies. There are, thus, three hydrocarbons containing two carbon atoms: C_2H_6 , C_2H_4 and C_2H_2 . Let us prepare them and study their properties.

Preparation of Ethane (C_2H_6)

Experiment 10.2

Arrange the apparatus as shown for the preparation of methane (Fig. 10.3). Heat a mixture of sodium propionate and soda lime in a hard glass test tube. Collect the gas by downward displacement of water.



Preparation of Ethylene (C_2H_4)

Experiment 10.3

Take 25 ml of ethyl alcohol in a flask and add slowly 50 ml of concentrated sulphuric acid. Gently shake the flask and cool it under the tap during addition of the acid. Add some aluminium sulphate to prevent frothing. Arrange the apparatus as shown in Fig. 10.9. Heat the flask and collect the gas by displacement of water.

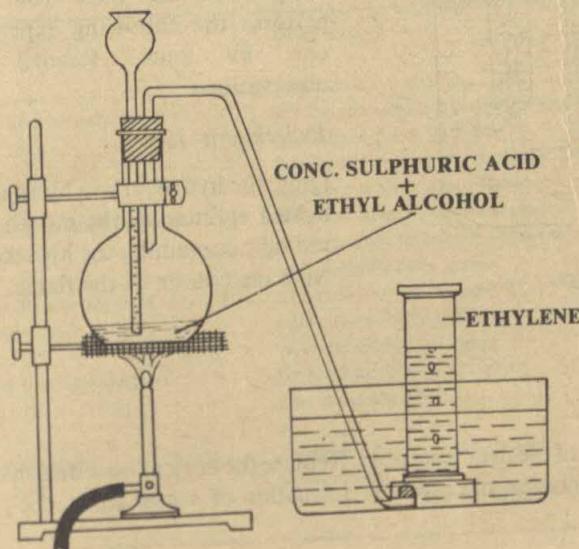
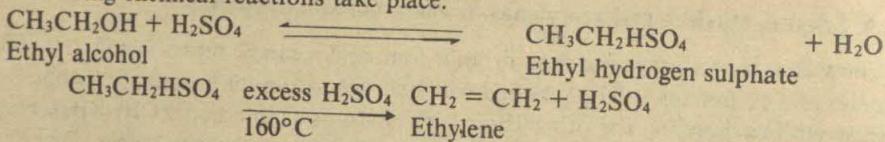


Fig. 10.9 Preparation of ethylene

The following chemical reactions take place.



Preparation of Acetylene (C_2H_2)

Experiment 10.4

Place 2 or 3 small pieces of calcium carbide in a test tube or a conical flask. Arrange the apparatus as shown in Fig. 10.10 for collection of acetylene. Add only a few drops of water at a time, and collect the gas.

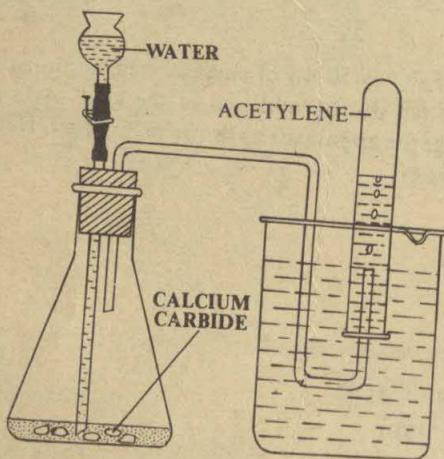
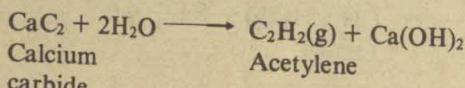


Fig. 10.10 Preparation of acetylene

All these three gases are insoluble in water, and so can easily be collected by downward displacement of water.

A study of the properties of methane, ethane, ethylene and acetylene: With samples of all these four gases perform the following experiments one by one. Record your observations.

Experiment 10.5

Ignite the hydrocarbon by applying a lighted splinter to the mouth of the test tube containing the hydrocarbon. Note the colour of the flame.

Experiment 10.6

Add 1 ml of bromine water to each of the four test tubes. Replace the cork at once and shake the mixture. Observe closely for any change in colour or formation of a new substance (e.g. a precipitate, a new smell).

Experiment 10.7

Dissolve a pinch (about 0.1 g) of sodium carbonate in 1 ml of 1% potassium permanganate solution. Add 5 drops of this solution to each of the four test tubes containing these four hydrocarbons. Shake the contents. Observe and carefully note for:

- (i) disappearance of colour
- (ii) formation of a new colour
- (iii) appearance of a precipitate
- (iv) any new smell that may appear after shaking.

Experiment 10.8

Prepare acidified potassium permanganate (KMnO_4) solution by adding 5 ml of dilute sulphuric acid to 2.5 ml of 1% KMnO_4 solution. Add 1 ml of acidified KMnO_4 solution to each of the four hydrocarbons. Shake well the mixture in a corked test tube. Note for any change of colour or formation of a new substance.

Experiment 10.9

Prepare an ammoniacal solution of cuprous chloride by dissolving it in dilute ammonium hydroxide solution. Add 5 drops of this solution to each of the four test tubes containing these four hydrocarbons. Note for any change of colour or formation of a precipitate.

An arrangement as shown in Fig. 10.11 may be used to pass acetylene gas in the solution.

If you perform these experiments, you would be able to note the following observations.

TABLE 2
Study of properties of methane, ethane, ethylene and acetylene

Sl. No.	Experiment	Observations	Inference
1.	Ignite the hydrocarbon (Expt. 10.5)	All the four gases burn; methane and ethane burn with non-luminous flame, and ethylene, acetylene with a sooty flame.	All the four gases are combustible.
2.	Treat with bromine water (Expt. 10.6)	Bromine water is decolourised by ethylene and acetylene; no action with the other two gases.	Ethylene and acetylene are unsaturated hydrocarbons; methane and ethane are saturated. (Same as above)
3.	Treat with alkaline KMnO_4 solution (Expt. 10.7)	There is decolorisation with ethylene and acetylene; no action with the other two gases.	
4.	Treat with acidic KMnO_4 solution (Expt. 10.8)	Only ethylene and acetylene decolorise the solution.	Ethylene and acetylene are oxidised by acidified KMnO_4 solution.
5.	Treat with ammoniacal Cu_2Cl_2 (Expt. 10.9).	Acetylene gives a reddish brown precipitate (Cu_2C_2).	Hydrogen atoms in acetylene are replaceable by metals, e.g., Cu. (Fig. 10.11).

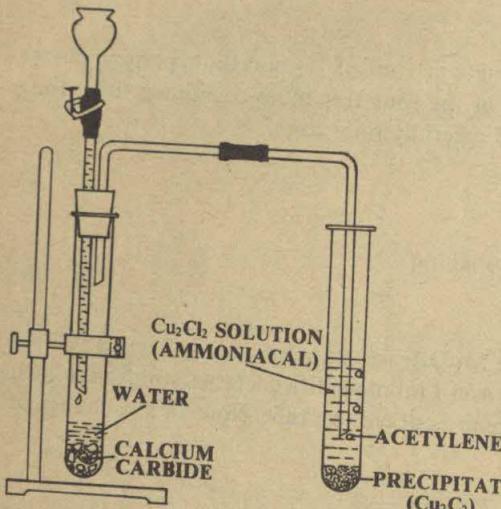
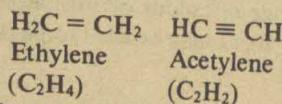


Fig. 10.11 Action of acetylene with ammoniacal solution of cuprous chloride

10.3.7 Classification of hydrocarbons : saturated and unsaturated

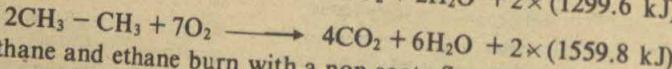
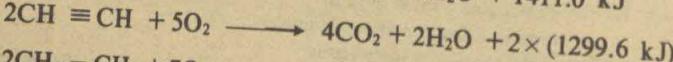
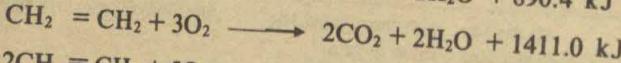
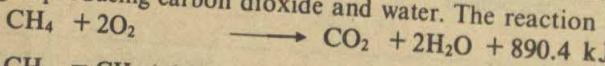
Unsaturation in organic compounds: You have learnt in Class IX that the sharing of two pairs (i.e., 4) of electrons results in the formation of a double covalent bond; and the sharing of three pairs (i.e., 6) of electrons results in the formation of a triple covalent bond. The molecules of methane and ethane have only single covalent bonds. They are known as saturated hydrocarbons. So all alkanes are saturated hydrocarbons. Ethylene and acetylene are unsaturated hydrocarbons, in them the carbon-carbon bonds are not single-covalent. In ethylene it is a carbon-carbon double bond, and in acetylene carbon-carbon triple bond as shown below:



From the experiments that you have performed above, you would note that saturated hydrocarbons are nonreactive, whereas unsaturated ones are reactive. Hence saturated hydrocarbons are also called paraffins (para = less; affins = affinity).

Let us now explain each reaction performed.

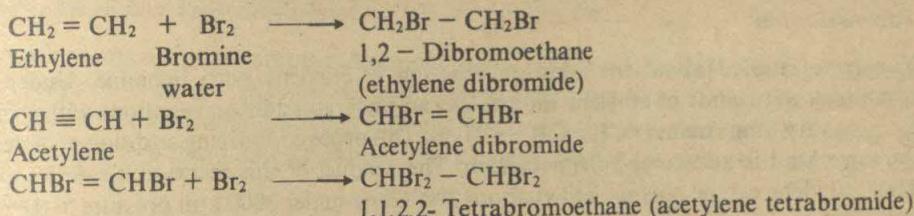
Combustion: Methane, ethane, ethylene and acetylene are all combustible gases. They burn in air/oxygen producing carbon dioxide and water. The reaction is highly exothermic.



Methane and ethane burn with a non-sooty flame, whereas ethylene and acetylene burn with a sooty flame. This is so because ethylene and acetylene have higher percentages of carbon which is not completely oxidised under ordinary conditions of burning. The yellow colour and sootiness in the flame is, therefore, due to carbon particles in the flame.

All these four hydrocarbons form highly explosive mixture with air (oxygen) and, therefore, need great care in their handling.

Test for unsaturation: Bromine water is quickly decolorised by unsaturated compounds like ethylene and acetylene giving ethylene dibromide and acetylene tetrabromide, respectively. In ethylene, one molecule of bromine adds, while in acetylene two molecules of bromine add as shown below:



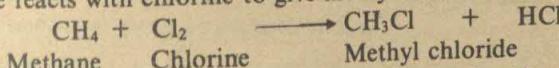
These reactions with bromine are called *addition reactions*. The double and triple bonds between carbon atoms are broken and converted into single bonds. The valencies of carbon atoms thus freed are saturated with bromine atoms.

Similarly with alkaline potassium permanganate also, ethylene and acetylene quickly react to show a colour change (green) and then a precipitate (brown).

Bromine water and alkaline $KMnO_4$ are reagents used to test for unsaturation in an organic compound. (Methane and ethane being saturated hydrocarbons do not react with these two reagents).

Acidified potassium permanganate does not react with methane or ethane, but it is decolorised by ethylene or acetylene.

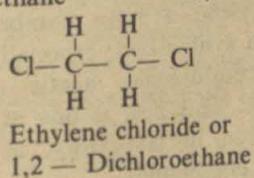
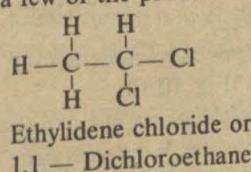
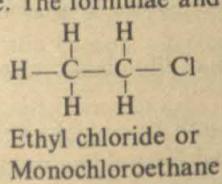
Reactions of saturated hydrocarbons with chlorine: The saturated hydrocarbons (CH_4 , C_2H_6) are inert and do not react with Br_2 water (no decolorisation). However, they do react with chlorine in the presence of light ($h\nu$), peroxides or at high temperatures. A reaction occurs in which hydrogen atom is replaced by a chlorine atom (substitution reaction). For example, methane reacts with chlorine to give methyl chloride (monochloromethane).



Methane Chlorine Methyl chloride
 The naming of the product CH_3Cl may be explained here. There are two ways of looking at the formation of this molecule: (i) one H atom of CH_4 has been substituted by one atom of Cl (hence the name monochloromethane, i.e., methane in which one H has been substituted by one Cl); (ii) a methyl group ($-\text{CH}_3$) has combined with a chlorine atom (methyl chloride).

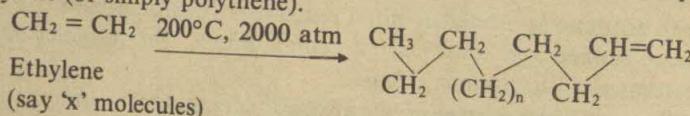
Further, reaction with chlorine in the presence of light or peroxides may give CH_2Cl_2 (dichloromethane, or methylene chloride), CHCl_3 (trichloromethane or chloroform), and C Cl_4 (carbon tetrachloride or tetrachloromethane).

All the six hydrogen atoms of ethane can similarly be substituted successively by atoms of chlorine. The formulae and names of a few of the products are given below:



Polymerisation

You have studied about the addition reaction of ethylene with bromine. Under certain conditions thousands of ethylene molecules can undergo addition reactions with themselves forming very long chains ($-\text{CH}_2-\text{CH}_2-\text{CH}_2-$). This process involving addition of molecules of the same kind is known as *Polymerisation*. The product of this reaction is called a *Polymer*. Thus, ethylene can be polymerised at about 200°C and under 2000 atm pressure to the polymer polyethylene (or simply polythene).



10.3.8 Uses of methane, ethane, ethylene and acetylene

All these four gases are used in general as fuels. They are also used as raw materials for making other substances.

Methane: Methane is a good gaseous fuel because it burns with liberation of a lot of heat. Since no smoke is produced while burning, its use is clean and hygienic.

Upon strong heating without air (pyrolysis), methane breaks down (or, cracks) into hydrogen and elemental carbon which is in a very finely divided state. This carbon is used in rubber industry.

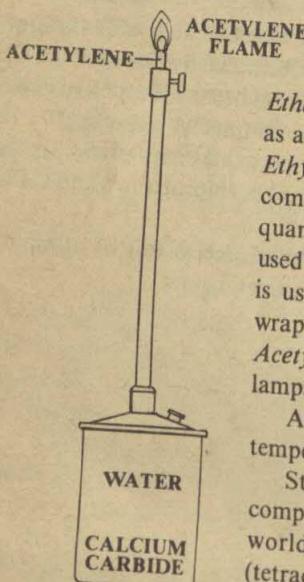
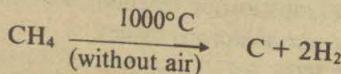


Fig. 10.12 Acetylene lamp

Ethane: Along with methane and other hydrocarbons it is also used as a gaseous fuel.

Ethylene: It is used for the manufacture of a number of organic compounds, such as ethyl alcohol and ethylene glycol. In small quantities, ethylene is used for artificial ripening of fruits. It is also used for the manufacture of plastics such as polythene, which in turn, is used to make household articles like buckets, mugs, bags, and wrappers.

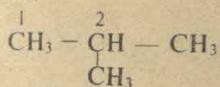
Acetylene: Acetylene is used as fuel and an illuminant in acetylene lamps. (Fig. 10.12)

Acetylene burns in oxy-acetylene torch to produce very high temperatures. Oxy-acetylene flame is used for welding metals.

Starting with acetylene, a large number of useful organic compounds have been synthesized, especially during the second world war, e.g., acetaldehyde, acetic acid, and westron (tetrachloroethane), etc. This now is one of the most important chemical industry. Even in laboratory, acetylene is used for preparation of organic compounds.

10.3.9 Nomenclature in hydrocarbons

The names of open chain saturated hydrocarbons or alkanes end in '-ane', e.g., methane, ethane, propane. How do we name the two butanes that correspond to the same molecular formula C_4H_{10} ? Butane with a straight unbranched chain of carbon atoms is called 'normal butane' or simply n-butane. The other butane having branched chain, as shown below, is called 'isobutane'.



iso-butane or 2-methyl propane

Another way of naming it is to consider it as a derivative of the parent hydrocarbon, propane, wherein one H-atom (that on the second carbon atom counting 1, from either end C-atom) has been substituted by a $-\text{CH}_3$ group. Hence, it is named as 2-Methyl-propane.

Hydrocarbons like ethylene, have been given the general name of *alkenes*. The ending -ane of an alkane is replaced by the ending -ene to indicate the presence of one carbon-carbon double bond in the molecule. On this basis another name for ethylene is *ethene*.

Hydrocarbons like acetylene are given the general name *alkynes*. A way of naming them is to replace '-ane' of the alkane name by '-yne'. Thus, another name for acetylene is *ethyne*.

10.4 FUNCTIONAL GROUPS

10.4.1 Functional groups and their nature

We studied above some similar and some dissimilar properties of ethane (C_2H_6), ethylene (C_2H_4) and acetylene (C_2H_2). Thus, all of them are combustible. We can explain this similarity on the basis of their composition; the molecules in all the three are made up of only carbon and hydrogen atoms. The three gases, however, differ also in some properties, e.g., reaction with bromine. Such difference in properties is due to the presence of a double bond in ethylene molecule, and a triple bond in acetylene.

Now, let us consider the following three compounds together, namely, methane (CH_4), chloroform ($CHCl_3$) and carbon tetrachloride (CCl_4). All the three differ in their physical and chemical properties. While methane is gas, the other two are liquid at ordinary temperatures. While methane is combustible, carbon tetrachloride is used for extinguishing fires. Unlike methane and carbon tetrachloride, chloroform is an anaesthetic compound. How can we explain such differences in properties?

Methane burns while carbon tetrachloride extinguishes fire because all the four C—H bonds of methane have been replaced by C—Cl bonds. While methane is the parent hydrocarbon molecule, —Cl, in $CHCl_3$ and CCl_4 , is a *functional group*. The functional group in ethylene is $-\text{C}=\text{C}-$, and in acetylene it is $-\text{C}\equiv\text{C}-$.

It is useful to regard an organic molecule as consisting of two parts: the reactive part or functional group and the non-reactive part, i.e., basic carbon chain. The functional group determines largely the chemical and physical properties of an organic compound. The size of the residual part affects mainly the physical properties.

10.4.2 Some more functional groups

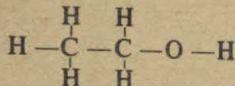
Let us perform some experiments to familiarise ourselves with three more functional groups, viz.,

Alcoholic functional group or hydroxyl group —OH

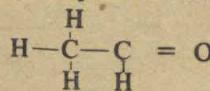
Aldehydic functional group —C=H or —CHO

Carboxylic functional group or acid group —C—OH or, —COOH

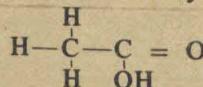
Let us take the following compounds, all derived from the parent hydrocarbon ethane, but containing only one of the above three groups to perform some experiments.



Ethyl alcohol (liquid, b.p. 78°C)



Acetaldehyde (liquid, b.p. 21°C)



Acetic acid (liquid, b. pt. 118°C)

Experiment 10.10

Cautiously smell the three liquids. Do they differ from one another in their smell? Prepare their aqueous solutions by mixing one volume of the liquid with four volumes of water. Try if you can identify these organic compounds in aqueous solutions on the basis of their smell, and behaviour towards litmus paper.

Experiment 10.11

Take 1 ml each of the three compounds in three test tubes. Observe which one of the three compounds evaporates fastest, and which one is the slowest to evaporate.

Experiment 10.12

Add a pinch of solid sodium bicarbonate to each one of the three liquids. What difference do you find?

Experiment 10.13

Add a small piece of sodium to 1 ml of ethyl alcohol in a test tube. Note what happens. Collect the gas in a test tube by displacement of water, and test for hydrogen with a burning splinter.

Experiment 10.14

Add dilute ammonium hydroxide solution drop by drop to about 1 ml of silver nitrate solution taken in a test tube, till the precipitate that first appears just redissolves. Add a few drops of acetaldehyde and warm the test tube in a beaker of boiling water. Note what you observe.

Study the following table for observations from these experiments.

Table 3
Study of the properties of alcoholic, aldehydic and carboxylic groups

S. No.	Experiment	Observations	Inference
1.	Smell; test with litmus paper (Expt. 10.10)	Each has a characteristic smell; Acetic Acid turns blue litmus red.	The three liquids can be identified on the basis of their smell.
2.	Observe for the evaporation of liquids. (Expt. 10.11)	All acetaldehyde first evaporates; and then all alcohol.	Only one of them is acidic in nature. Acetaldehyde is the most volatile and acetic acid the least of the three liquids.
3.	Add solid sodium bicarbonate (Expt. 10.12)	Brisk effervescence with acetic acid only.	Only acetic acid has a carboxylic group. (test for acidic group).
4.	Add sodium piece to ethyl alcohol (Expt. 10.13)	Effervescence, the gas produced in the reaction can be burnt.	Ethyl alcohol has hydrogen atom replaceable by sodium (test for alcoholic group).
5.	Test acetaldehyde with ammoniacal silver nitrate solution, i.e., Tollen's reagent (Expt. 10.14)	Deposit of shining silver.	Acetaldehyde reduces Tollen's reagent. (test for aldehydic group).

From the above experiments you will be able to appreciate the difference that the presence of a functional group can make on the properties of a parent hydrocarbon. All these three compounds can be regarded as derivatives of C_2H_6 by substitution of one H by an — OH in ethyl alcohol; by replacement of two H atoms by an oxygen atom in acetaldehyde, by replacement of all the three H atoms of one CH_3 group (two by an oxygen atom and one H by an — OH group) in the case of acetic acid. Yet, how different these are from one another!

10.5 ETHYL ALCOHOL (C_2H_5OH)

Ethyl alcohol is also known as ethanol. This name is derived from the name ethane, which is the parent hydrocarbon. The ending 'e' in ethane is substituted by the ending 'ol' in ethanol, indicating substitution of an H by an — OH group. Ethyl alcohol is produced in some reactions of the type called 'fermentation'. Let us first try to understand this term.

10.5.1 What is fermentation?

Experiment 10.15

Keep some milk in a glass container. Observe what happens to it upon keeping for quite some time, say 3 or 4 days. How many hours does the milk take to turn into something like curd? Keep for another day or two. Note for any peculiar smell or changes in smells throughout the experiment.

Experiment 10.16

Take some boiled milk in a glass container. Allow it to cool and when lukewarm add a few drops of curd to it. How long does the milk take to change into curd? Keep for another two or three days and note the changes in colour, and smell.

You may cite many examples of such chemical changes taking place in your environment at ordinary temperatures (e.g., kneaded flour getting sour on keeping). These changes are due

to the presence of a certain substance of a catalytic nature. A catalyst is a substance that enhances or retards the rate of a reaction by its mere presence. In the above cases, the catalyst is of bio-chemical nature. One such catalyst named lactic ferment turns milk sugar (called lactose) into an acid (lactic acid). Another bio-chemical catalyst named butyric ferment leads to the formation of butyric acid (which has a characteristic smell of putrid cheese). The bio-chemical catalysts are present in all living bodies. They serve to catalyse all the diverse functions of the living body. They are also known as enzymes which literally means 'within yeast'.

Chemical reactions involving enzymes were known to man from very early times. An example is the change of grape juice or sugar solution to liquid mixtures containing alcohol upon addition of yeast. This change was called fermentation because the liquid appeared to be boiling (fervere = to boil). This was due to liberation of CO_2 gas. Another name for the catalyst promoting fermentation is, therefore, 'ferment'.

Fermentation is used for the industrial preparation of ethyl alcohol from molasses which is a by-product of the sugar industry—a major agro-industry of our country. Molasses contains cane sugar that could not be crystallised out during production of cane sugar from concentrated sugar cane juice. By fermentation the cane sugar is converted into ethyl alcohol and carbon dioxide.

10.5.2 Properties of ethyl alcohol

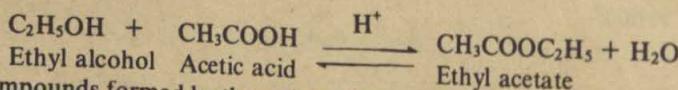
You have already studied the reaction of ethyl alcohol with sodium (Expt. 10.13), equation for which is as given below:



Sodium ethoxide
Let us study some more properties of ethyl alcohol.

Experiment 10.17 (Ester test)

In a dry test tube, take 5 drops of ethyl alcohol and 5 drops of glacial acetic acid. Add also one drop of concentrated sulphuric acid and warm the mixture on a water bath. Pour the mixture into ice-cold sodium bicarbonate solution and notice the sweet smell. This is due to the formation of ethyl acetate.



Compounds formed by the action of an alcohol with an acid are known as esters, and this reaction is called *esterification*.

Experiment 10.18 (Mild oxidation)

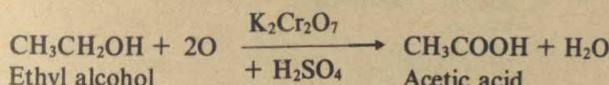
Gently heat some cupric oxide or copper (II) oxide in a test tube. Add it to about 5 ml ethyl alcohol kept in an evaporating basin. Do you notice any peculiar smell? This is due to formation of acetaldehyde. While ethyl alcohol is oxidised to acetaldehyde, copper (II) oxide is reduced to copper.



Experiment 10.19 (Strong oxidation)

Take some ethyl alcohol in a test tube, and add to it a concentrated aqueous solution of potassium dichromate. Pour a few drops of dilute sulphuric acid into this mixture and heat gently. Note for any change of colour.

The mixture of potassium dichromate and sulphuric acid is a strong oxidising agent. Ethyl alcohol is oxidised to acetic acid in this reaction.



10.5.4 Harmful effects of drinking alcohol

'Alcohol' is the general name for organic compounds containing the hydroxyl ($-\text{OH}$) group. For example, methanol (CH_3OH), ethanol ($\text{CH}_3\text{CH}_2\text{OH}$), propanol-1 ($\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$) may all be referred to as different alcohols. However, the term 'alcohol', also refers specifically to ethanol or ethyl alcohol. The ignorance of this fact creates many a time serious problems. While assuming that they are drinking ethyl alcohol, some persons either due to ignorance or prevalent adulteration practices, ingest other alcohols which are poisonous. For example, methanol (methyl alcohol) when ingested even in small quantities causes severe poisoning accompanied by loss of eyesight. Consumption in larger quantities can be fatal. So you should keep in mind that the term 'drinking alcohol' stands for 'drinking ethyl alcohol' only.

Alcohol has very harmful effects on the human body. It is an intoxicant. A person loses all sense of discrimination under its influence. He is unable to distinguish between good and bad, or right and wrong. A person consuming even small quantities of alcohol gradually gets addicted to its use. Alcoholism may ultimately lead to total economic disaster of a family, besides ruining the health of the person concerned. We should restrain ourselves from keeping company of such addicts. We should shun consumption of alcohol on any pretext, because once started, the habit will lead to total disaster.

Alcohol is, however, also a product of great importance in national economy. Large quantities of it are used in the manufacture of synthetic rubber, lacquers and varnishes, medicines, etc. Alcohol for industrial purposes is denatured by the addition of substances, e.g., methyl alcohol, pyridine, CuSO_4 , etc. that make it unfit for drinking.

10.6 FORMALDEHYDE (HCHO)

You may have visited a biology laboratory and observed some peculiar smell near the preserved specimens. This peculiar smell (pungent) is due to formalin, which is an aqueous solution of formaldehyde (HCHO) in water. Theoretically, formaldehyde is a derivative of methane. Besides the characteristic smell, the following tests can also be performed using formalin.

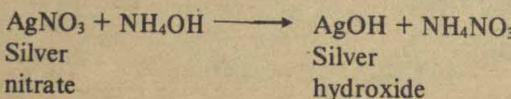
Experiment 10.20 (Silver mirror test)

Take 1 to 2 ml of a 5% solution of silver nitrate in a thoroughly washed test tube. Add to it ammonium hydroxide solution, drop by drop. A precipitate is formed. Continue addition of

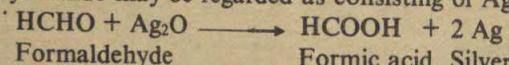
NH_4OH drop by drop till the precipitate just redissolves. This is known as ammoniacal silver nitrate solution or, simply Tollen's reagent. Now add to the test tube one or two drops of formalin. Put the test tube in a hot water bath (60°C) for some time. What do you observe?

You may find a black precipitate of metallic silver at the bottom of the test tube, and a shiny silver mirror deposited on the walls of the test tube.

The reaction may be explained as given below.

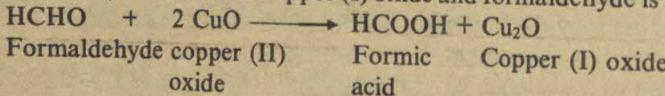


Silver hydroxide may be regarded as consisting of Ag_2O and H_2O .



Experiment 10.21

Take some freshly prepared Fehling's solution¹ in a test tube. Add about 1 ml of formalin to the Fehling's solution. Boil the mixture for a few minutes. What do you observe? A red precipitate of cuprous oxide or copper(I) oxide is formed. In this reaction copper(II) oxide (present in Fehling's solution) is reduced to copper (I) oxide and formaldehyde is oxidised to formic acid.



10.6.1 Uses of formaldehyde

Formaldehyde is a strong disinfectant. It is used in the form of its aqueous solution (formalin) for preservation of biological and anatomical specimens.

Formaldehyde is used as a starting material for preparing many substances that have extensive application. Some of these are mentioned below:

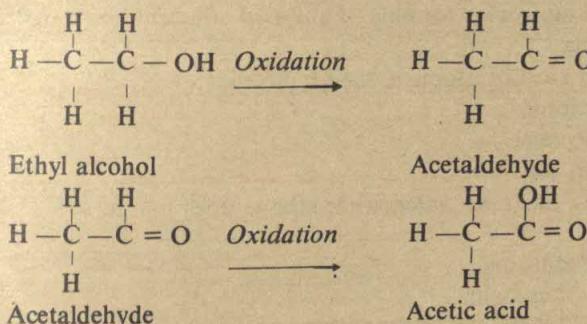
- With ammonia it forms urotropane, an important medicine for urinary troubles.
- with phenol and other substances it gives resins which serve to make plastic substitutes for horn, porcelain, gutta-percha and metals.
- in the manufacture of certain dyes.
- for the manufacture of sole leather and water proof fabrics.

10.7 ACETIC ACID (CH_3COOH)

You may be familiar with vinegar which is used as a pickling agent. Some like to use vinegar as an appetiser for dressing their food dishes at times. Vinegar is obtained by bacterial oxidation (a fermentation or enzymic reaction) of ethyl alcohol. It is a dilute solution of acetic acid in water containing other substances that give to it its special flavour.

¹ Fehling's solution is prepared as follows:

34.6 g of copper sulphate are dissolved in 1 litre of water in one flask; 177 g of Rochelle salt (sodium-potassium tartarate) and 60 g of sodium hydroxide are dissolved in 1 litre of water in another flask. The two solutions are mixed directly for use as Fehling's solution. It has always to be prepared fresh by mixing the two solutions, because it cannot be kept for a long time.



EXERCISES

1. Why are organic compounds studied as a separate branch of chemistry?
2. Define the terms: (i) Organic chemistry
(ii) Organic compound.
3. Name two organic compounds which are obtained from plant sources, and two which are obtained from animal sources.
4. Why are organic compounds so large in number?
5. Give two examples of each of the following:
 - (i) Saturated hydrocarbons.
 - (ii) Unsaturated hydrocarbons.

Write names and structural formulae of the examples you give.
6. Write the structural formula of a saturated hydrocarbon containing 3 carbon atoms in its molecule.
7. What is the general name given to all the compounds containing only carbon and hydrogen?
8. The general molecular formula of alkanes is C_nH_{2n+2} . What will be the general molecular formula for:
 - (i) alkenes
 - (ii) alkynes
9. Classify the following compounds as alkane, alkene or alkyne:
 C_3H_4 , C_2H_6 , C_2H_4 , C_6H_{14} , C_2H_2
 Explain how did you arrive at your conclusion in each case.
10. What do you understand by homologous series? Explain giving one example of a homologous series.
11. Select hydrocarbons which are members of the same homologous series. Give also the name of each homologous series you find represented in the following:
 CH_4 , C_2H_2 , C_2H_4 , C_2H_6 , C_4H_{10} , C_3H_4 , C_3H_6 .
12. Write the structural formula of the first three homologues of alkane series.
13. Write the structural formulae of:
 - (i) first four members of the homologous series of alkanes.
 - (ii) first two members of the homologous series of alkenes.
 - (iii) first two members of the homologous series of alkynes.
14. What are the characteristic features of a homologous series?

15. What is the difference in the molecular formula of any two adjacent homologues?
 (i) in terms of molecular mass.
 (ii) in terms of number and kind of atoms in their molecules.

16. Complete the following reactions:

$$\text{CH}_2 = \text{CH}_2 + \text{Br}_2 \text{ (aq)} \longrightarrow$$

$$\text{CH} \equiv \text{CH} + \text{Br}_2 \text{ (aq)} \longrightarrow$$

17. Why does ethylene decolorise bromine water, while ethane does not do so?

18. Give one example each of:
 (i) an addition reaction of chlorine.
 (ii) a substitution reaction of chlorine.

19. Which of the following compounds will give an addition reaction?
 $\text{C}_2\text{H}_6, \text{C}_3\text{H}_8, \text{C}_2\text{H}_4, \text{C}_3\text{H}_4, \text{C}_2\text{H}_2, \text{C}_6\text{H}_{14}$

20. What do you understand by isomerism? Illustrate with examples.

21. How many isomers of the molecular formula C_4H_{10} are possible? Write their structural formulae.

22. Name the products obtained by the combustion of saturated and unsaturated hydrocarbons.

23. How will you prepare methane and ethane gases in the laboratory? Give equations for the reactions involved. Also draw diagrams.

24. Give the uses of the following organic compounds:
 (i) Methane, (ii) Ethylene, (iii) Acetylene.

25. What is meant by a functional group? Give examples.

26. Name three different functional groups, giving examples of the compounds that contain them.

27. Ethane burns in oxygen to form carbon dioxide and water. Write balanced chemical equation for this reaction.

28. What functional groups are present in CH_3CHO and $\text{CH}_3\text{CH}_2\text{OH}$? How will you test for these functional groups?

29. Complete the following statements:
 (i) The next higher homologue of ethane is _____.
 (ii) Compounds of carbon and hydrogen are called _____.
 (iii) Butane is a _____.
 (iv) Acetylene is an _____.
 (v) Oxyacetylene flame is used in _____.
 (vi) Valency of carbon in ethylene is _____.
 (vii) The process of burning of a hydrocarbon in presence of excess of air to give $\text{CO}_2, \text{H}_2\text{O}$, light and heat is known as _____.
 30. What are the effects of drinking alcohol on a human being? How can they be very disastrous to the family as well as the person himself?

31. Give the uses of the following compounds:
 (i) Formaldehyde
 (ii) Acetylene
 (iii) Acetic acid
 (iv) Ethyl alcohol

32. What do you understand by fermentation? Give two common examples of fermentation.
33. Draw a neat labelled diagram of the apparatus you can use for the preparation of acetylene in the laboratory. Write chemical equation for the reaction of acetylene preparation.
34. Draw three-dimensional structures for the molecules of methane and ethane.
35. How will you test for the presence of the following functional groups in organic compounds?
 - (i) hydroxyl group
 - (ii) aldehydic group
 - (iii) carboxylic group
36. What do you understand by 'unsaturation'? How will you test for unsaturation in an organic compound?

UNIT 11

Chemistry in the Service of Man

Man is a living being and as such has basic needs such as, food, shelter, clothing, personal health, and protection against disease. Moreover, man lives in a society and as a social being his needs range from travel and transport to recreation and recording of events (e.g., using camera and tape recorder). Chemistry, as the science of materials, is of immense service to man in respect of his material requirements for comfort and fulfilment of needs as mentioned above.

Chemistry also plays a prominent role in the development of national economy. There is hardly any aspect of national economy wherein the knowledge and methods of chemistry are not employed; be it agriculture or industry, construction of houses, or dams and bridges, of roads, canals or railway tracks. Wherever materials are required in bulk, chemistry stands in good stead to serve. Some examples of economic activities, at national level in which chemists (and their knowledge of chemistry) play a vital role are: metallurgy, petroleum and pesticides, textiles, soaps and synthetic detergents, dyes and drugs, agro-based industries like cane sugar, coffee, tea, rubber, etc.

Chemistry, thus, helps in the processing of products obtained from natural sources, e.g., leather from animal skin, sugar from sugar cane juice, rubber from the latex of rubber plants and so on. Even more important is the role of chemistry for the manufacture of new materials which can serve as substitutes for the natural material (e.g., synthetic rubber as a substitute for natural rubber). Moreover, there is at times a demand for new type of materials possessing a rare combination of properties, e.g., hard and strong, yet light and corrosion-resistant. Chemistry helps in the synthesis of such new materials as well.

In the following sections of this unit we will discuss the role of chemistry in some aspects of its service to man.

11.1 NATURAL AND SYNTHETIC RUBBER

11.1.1 Natural rubber

Rubber from latex: Natural rubber (or Plantation rubber) is obtained from some plants which exude (give out) a white liquid, called latex, upon being cut. The latex is contained in a network of narrow tubes (called latex vessels) in the walls of which the latex is secreted. The latex vessels are opened by making an incision in the bark of the tree. The incision is not horizontal. It slopes from left to right, and extends at its lower end into a vertical channel terminating in a metal spout below which is kept a cup for collecting latex.

The rubber content of latex is 30 to 40%. The latex is strained and diluted to about 12 to 20% concentration of rubber, and acetic acid (1%) is then added to it to coagulate rubber from the latex. The coagulation takes about 3 to 4 hours. Natural rubber so obtained is converted into sheets for marketing.

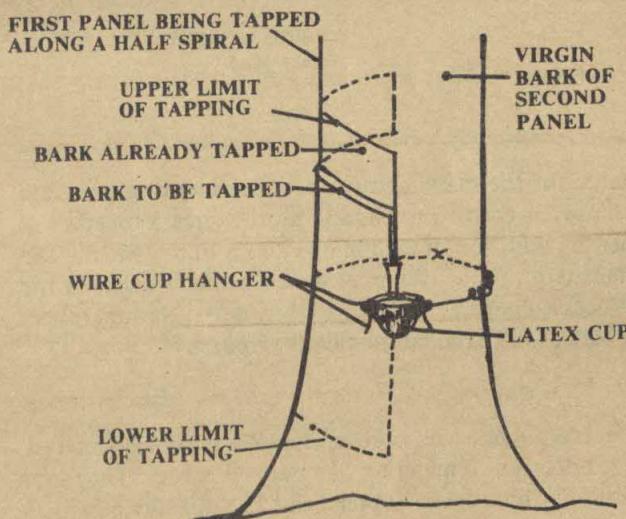


Fig. 11.1 Collection of latex

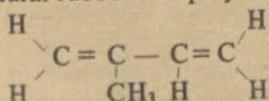
During 1983-84 India produced 1,75,280 tonnes of natural rubber and imported 35,940 tonnes of it:

Natural rubber—properties and uses: Columbus, during his 1492 expedition found that the natives used the rubber tree latex to make bouncing balls and water-proof shoes. In the early 19th century natural rubber began to be used for making water-proof materials. Things made of natural rubber, however, did not work well in warm weather. Chemists soon found methods to improve the quality of natural rubber, so that it was more durable and useful.

Natural rubber has a number of unique properties, the most important of which is its elasticity. A metal wire may be stretched to the extent of 1% without permanent deformation.

Rubber goods may be stretched to give increases of 100% to 1000% in length, and they would quickly return (called retraction or snap) to their original size upon release. The structure of rubber forms the basis of its unique properties.

Natural rubber is a polymer of isoprene (C_5H_8):



Isoprene (Molecular mass 68)

There may be 11,000 to 20,000 isoprene units in the polymer chain of natural rubber.

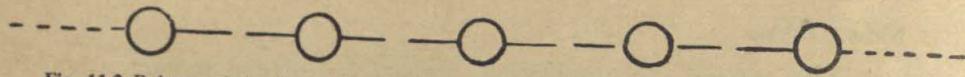


Fig. 11.2 Polymer chain of natural rubber (—O—represents isoprene unit).

Vulcanisation of natural rubber: If natural rubber is heated with sulphur its properties are markedly changed. This process is known as *vulcanisation*. Some properties of natural (or raw) rubber are compared with those of vulcanised rubber in Table 11.1.

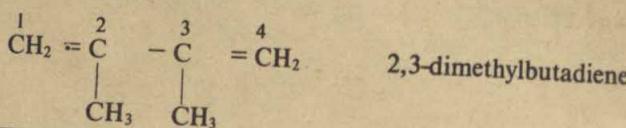
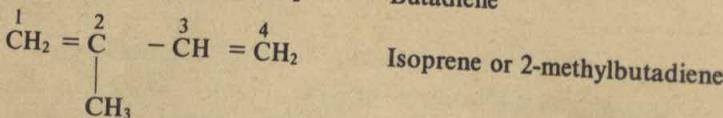
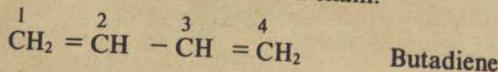
TABLE 11.1
Comparison of properties of raw and vulcanised natural rubber

Property	Raw rubber (Natural rubber without vulcanisation)	Vulcanised natural rubber
Tensile strength (pounds per sq. in.)	300	3,000
Temperature range for use	10°C to 60°C	—40°C to +100°C
Rapidity of retraction (i.e., snap)	Good	Very good
Water absorption	Large	Small

Vulcanised natural rubber is suitable for the manufacture of rubber bands, gloves, and tubing. However, it is too soft for such uses as conveyor belts and motor tyres. Properties of natural rubber may further be modified by addition of carbon black as a filler¹ (which gives strength to rubber) and an anti-oxidant (e.g., diphenylamine) which protects rubber from deterioration on exposure to the air. Processed natural rubber may then have : Natural rubber (100 parts), sulphur (3 parts), carbon black (50 parts), anti-oxidant (1 part).

11.1.2 Synthetic rubber

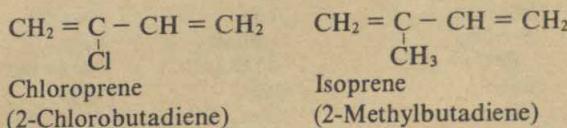
With the knowledge that natural rubber is a polymer of isoprene, chemists developed interest, around the year 1900, in the artificial production of materials like natural rubber. They soon found out that unsaturated hydrocarbons like butadiene, isoprene and 2, 3-dimethylbutadiene can be polymerised to rubber-like products. Study the formulae given below, and note the similarity of structure of the carbon chain.



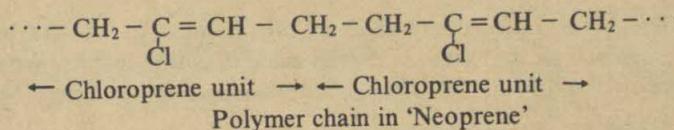
¹ Filler is a solid substance added to paints, plastics and rubber to modify their physical properties and reduce the cost.

A rubber like substance was first prepared, in 1902, by the polymerisation of dimethylbutadiene. By 1912, Germans started producing about 30 tonnes a month of synthetic rubber. The synthetic product was, however, not good. Further, research improved greatly the properties of synthetic rubbers for diverse uses. During the World War II (1939-1945) production of synthetic rubber received a tremendous boost, because supplies of natural rubber were either cut off or not enough to meet the enhanced needs. Let us discuss about Neoprene and Thiokol as examples of synthetic rubber.

Neoprene: Neoprene was first prepared in 1931 by polymerisation of chloroprene, a compound very similar in structure to isoprene.

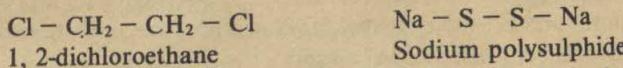


The polymer of chloroprene, called neoprene, was found to have a structure similar to that of natural rubber:

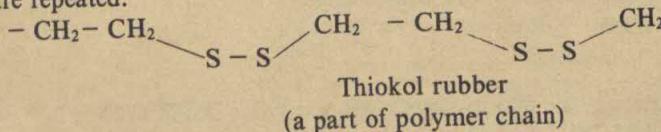


Neoprene has some properties which are not possessed by the natural rubber. For example, neoprene is non-inflammable, while natural rubber can be burnt. This is because of the presence of a large number of chlorine atoms in the molecule of neoprene. Also, neoprene has higher temperature resistance (i.e., retains its usefulness over a wider range of temperature) and it is also more resistant to action of oils and solvents than natural rubber. Neoprene is, therefore, especially useful for insulation of electric wires, such as, in motor engines, where these come in contact with oils. Neoprene is also widely used in hoses used for handling oils and solvents. In coal mines, the conveyor belts made of neoprene are used because there is no risk of the belt catching fire.

Thiokol: Thiokol rubber is prepared by reacting 1, 2-dichloroethane with sodium polysulfide.



Like neoprene or natural rubber thiokol has also long chains wherein units such as given below are repeated.



Thiokol rubbers are very good for their resistance to oils and solvents. They are widely used in the manufacture of hoses and tank-linings needed for handling and storage of solvents. Thiokol rubber, mixed with oxidising agents, forms an excellent rocket fuel. For example, the fuel in Polaris missile¹ is largely made up of Thiokol rubber.

1 A missile of the United States navy.

Study the following table for a comparison of some properties of different rubbers.

TABLE 11.2
Some properties of rubber

Properties	Type of rubber		
	Natural (vulcanised)	Neoprene	Thiokol
Tensile strength (pounds per sq. in)	3000	3000	1200
Elongation at break point (in %)	800	800	400
Tear resistance	Excellent	Good	Poor
Abrasion resistance	Excellent	Excellent	Poor
Useful Temperature range	-40°C to 100°C	-40 to 100°C	-40 to 100°C
Oil and solvent resistance	Poor	Good	Good
Oxygen and Ozone resistance	Poor	Good	Good

11.2 NATURAL AND MAN-MADE FIBRES

We are familiar with different types of materials which are used to make our dresses. In winter we wear woollens and in summer we prefer to use dresses made of cotton textiles. We also use garments of silk, or more often, artificial silk. These textiles are made from different types of fibres, namely cotton, wool and silk.

11.2.1 Natural fibres

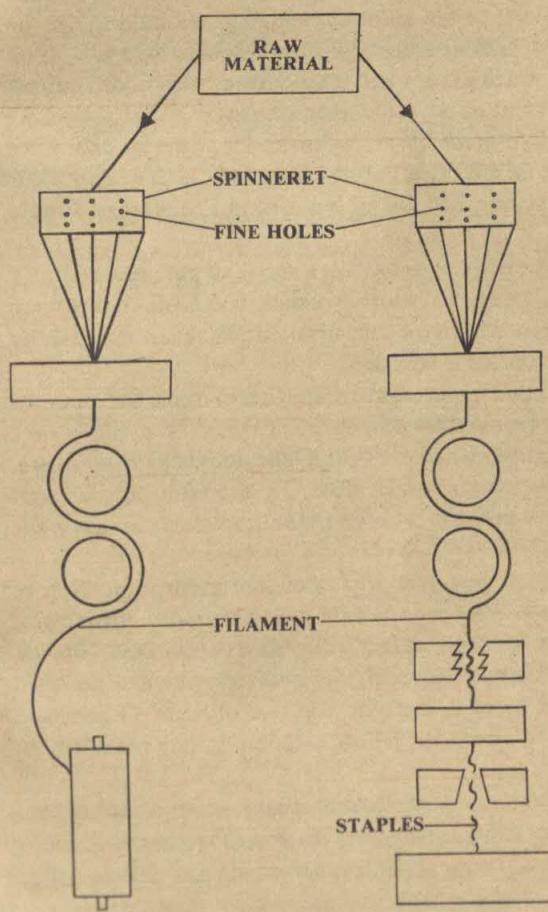
Among naturally occurring fibres, both cotton and wool are quite common in use. You must be already familiar with their sources. Both cotton and wool are useful for preparing fabrics, and then dresses because they prevent the loss of body heat to the atmosphere and thus help us to keep warm. When we feel too warm, these fibres also allow the sweat to pass through to outside. This is a great relief to us, especially in hot humid weather. However, cotton and wool have certain drawbacks as well. Woollen garments do not retain creases. They shrink on ordinary washing and are attacked by moths. Cotton fabrics also shrink to some extent on washing. Creases ironed into cotton fabrics are not retained on washing. Cotton dresses, though not eaten by moths, are readily attacked by mildew and mould. They are also highly inflammable.

Silk is another type of natural fibre. It is used for making cloth from very early times. Silk fibres are obtained from cocoons of silk worms. Silk worms spin a continuous filament of silk—very thin and yet very long. Silk thread is obtained by twisting together these filaments. Saris made of natural silk are good but very costly these days.

11.2.2 Man-made fibres

Besides these natural materials for making cloth, man has also made artificial or synthetic fibres. As in the case of rubber, here, too, chemical research has helped in the preparation of new materials with new sets of desirable properties. Many a time these man-made fibres are obtained by processing some natural product, e.g., viscose rayon (discussed later). Chemists have also prepared synthetic fibres (e.g., nylon and terylene) for the manufacture of which a natural product like cellulose or a protein is not the starting material.

In the preparation of all man-made fibres, there is one common mechanical process. The raw material, out of which the fibres are to be made, is passed through a spinneret (containing very fine holes) to produce long fibres. The raw material for this treatment is either dissolved in some solvent, or, is in a molten condition. Temperature and other conditions are such that as the material passes through the fine holes, the filaments thus formed are stabilised to retain their shape. This may be due to some physical change (e.g., evaporation of the solvent) or a chemical change in the raw material being processed into filaments or staples (i.e., small pieces of filaments).



Rayon as an example of man-made fibre from natural raw materials: The artificial silk prepared from cellulose is called rayon. Of the several varieties of rayon, the one produced by viscose is perhaps the most common. To prepare viscose rayon, cellulose in the form of wood pulp is treated with a strong solution of caustic soda, and then dried. The product is treated with carbon disulphide to give a yellow solid. This solid is dissolved in dilute caustic soda solution. Filaments are formed by passing the solution through a spinneret into dilute caustic soda solution.

Chemists have discovered methods to improve the properties of rayon. Two methods may be mentioned here as examples: (1) slowing down the speed at which the viscose solution flows through the holes in the spinneret; (2) stretching the newly formed filaments as much as possible without their breaking. By such treatments the tensile strength (i.e., strength needed to break

Fig. 11.3 Manufacture of filament yarn or/and staple fibre

fibre under the effect of a stretching force) of rayon fibres increases considerably.

This improvement in quality of rayon raised its consumption for various uses considerably. For example, let us consider the consumption in making tyre cord. In 1940, the total production of tyre cord used 3% rayon and 97% cotton. In 1950, the proportions were: 42% cotton, 57% rayon and 1% nylon. By 1960 cotton consumption in this field became almost nil, and the consumption of nylon increased appreciably. All this data is given to show how chemical research influences our production processes both at national and global levels.

Uses of rayon: Rayon fibres are first obtained in the form of long continuous filaments. They are used as such for purposes like tyre cord manufacture. For the manufacture of textiles they are cut into short lengths known as staple (Fig. 11.3). Rayon staple may be spun and woven on its own; or blended with cotton, wool or linen for this purpose. Mixtures (50%—50%) of rayon and cotton are used for nurses' dresses, aprons and caps. Rayon staple mixed with wool in equal quantities is used in the manufacture of carpets. In the medical field, e.g., in making lint or gauze, rayon is remarkably superior to cotton. This is because rayon can absorb over 90% of its own weight of water, and can be obtained in much purer form than cotton. Also rayon gauzes do not adhere to the wounds to the same extent as do the cotton gauzes.

Nylon and terylene as examples of synthetic man-made fibres: Nylon and terylene are examples of synthetic man-made fibres. They are not just modified natural materials, as for example is rayon—a regenerated cellulose. They are synthesised by polymerisation of rather simple molecules.

Properties and uses of nylon: Nylon was first obtained in 1935 as a result of pure research. By 1937, it was shown to be suitable for making bristles of tooth brushes. Nylon stockings were marketed first in 1939, and 64 million pairs were sold in the very first year. What an astonishing success for a new material being put to market for a new use!

The great strength of nylon thread is its most important property responsible for many of its uses. Quite heavy loads can be suspended from rather thin cords of nylon. So nylon is very good for such purposes as making of fishing nets, parachute fabric, cords and climbing ropes.

The nylon climbing ropes are light, very strong and flexible. They do not become stiff either at low temperatures or when wet. These properties make nylon immensely suitable for making climbing ropes.

Another important property of nylon is its low degree of moisture absorption. Nylon, therefore, dries out very rapidly, and possesses what is popularly called 'drip-dry' properties. Mention may be made here of the use of nylon in the manufacture of ladies' stockings. This use was the first major market success for nylon. There are several properties of nylon that makes it very suitable for this specific use. The property of drip-dryness is one of them. Others are, strength with extreme fineness, that is achievable with nylon, flexibility and retention of original shape after use.

Wool may be blended with nylon to increase its strength and resistance against abrasion. This blending with nylon gives woollen garment a much increased life. For example, men's socks made of nylon-mixed wool (75% wool, 25% nylon) wear about five times as long as pure woollen socks. In carpet manufacture nylon staple is used for blending with either wool or rayon to enhance the carpet's resistance to wear.

Properties and uses of terylene: In many respects terylene is similar in its properties to nylon. It is strong, thermoplastic¹ and very resistant to action by chemical or biological agents. The low

¹ A plastic which can be melted by heat for moulding, and can be remelted repeatedly after solidification without a substantial change in its physical and chemical properties, would be called a thermoplastic.

moisture absorbing property makes terylene clothing dry out very rapidly after washing. The creases set into terylene fabrics are fast and long lasting, because of the heat-setting quality¹ of terylene. The terylene clothes suffer little unwanted creasing from crumpling and washing, etc. This quality of terylene is very important for its widespread use in the manufacture of textiles. For example, mixed with wool, terylene is widely used for the manufacture of suitings, and blends of terylene with cotton for making shirts, etc.

A few more uses of terylene are:

- (i) Terylene sails—these are light, strong, do not stretch, and do not rot in contact with water. Terylene is more suitable than nylon for this purpose.
- (ii) Protective clothing for workers in industries—these are resistant to action by chemicals.
- (iii) Fire hoses—these are strong and quick drying, and do not deteriorate when stored wet.

11.2.3 Distinction between cotton, wool, silk and artificial fibres

Experiment 11.1

Suspend textile fibres to be tested and distinguished, from some support. Bring a burning match stick to each one of them at their lower ends. Allow them to burn for some time and make observations. Draw inferences about the nature of fibres on the basis of information given below:

- (i) Cotton, viscose and linen burn vigorously without forming a bead. They give out a smell of burning paper.
- (ii) Wool, silk and regenerated protein fibres (i.e., man-made fibres out of a proteinous natural material) burn but not vigorously. They do not form a bead, and give smell of burning feathers.
- (iii) Nylon, terylene and acetate rayon (i.e., cellulose acetates) fibres burn slowly. They form a bead due to melting of the material of fibres.

11.3 INDUSTRIAL CHEMISTRY

This section of the unit deals with a few selected industries in which chemistry plays a prominent role. You will be able to appreciate the role of chemistry in our national economy after studying this section.

11.3.1 Coal and its products

Coal is regarded as the backbone of the energy sector of our national economy. This is so because it is found in abundance in our country—an estimated total reserve of 31,888 million tonnes down to 300 metres depth. The big coal mines in our country are in Bihar (Jharia and Bokaro) and West Bengal (Raniganj). Coal is important because it can easily be converted into other forms of energy like gas, electricity or even oil. Coal is also the source of many important chemicals used for manufacture of dyes, drugs, etc.

¹ It is a property by virtue of which any material (e.g., terylene) may be set to any desired shape under hot conditions (e.g., Ironing with a hot press).

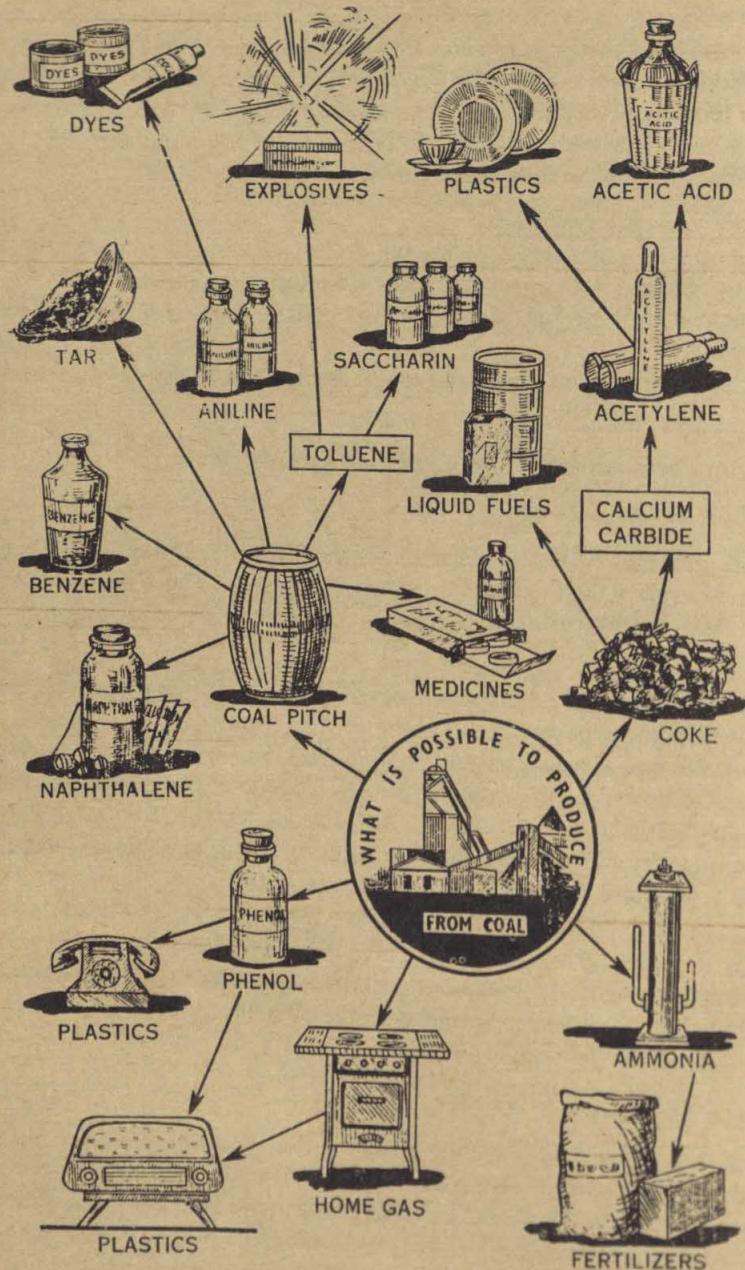


Fig. 11.4 Coal and its products

Coal mining was started at Raniganj in West Bengal in 1774. After independence, the coal mining industry, like so many other activities necessary for our economic growth, was stepped up. The production of 3.20 crore tonnes in 1950 increased to 13.83 crore tonnes in 1983-84.

Coal was formed millions of years ago by the decomposition of plants that once grew over the surface of the earth. According to geologists, during certain periods violent changes (earthquakes and volcanoes) took place on the earth. As a result forests were buried under ground and covered with sand, clay and water. Inside the earth these plants and trees were subjected to high temperature and pressure. Chemical changes took place which converted plant matter into coal. The process is called *carbonisation*. It is a very slow process and may have taken tens, or even, hundreds of thousands of years. Several intermediate products of carbonisation are known such as peat, lignite, bitumen (soft coal) and anthracite (hard coal). They have different carbon contents. In fact coal is a complex mixture of substances containing carbon compounds and free carbon.

Dry distillation of coal (i.e., strong heating in absence of air) provides us many valuable and important products. Study the figure given on p. 190 and identify names of things with which you are familiar. The solid residue left behind after dry distillation of coal is known as coke. It is used in iron metallurgy as a reducing agent.

11.3.2 Petroleum and its products

Petroleum—Its origin and occurrence: Petroleum is a dark coloured oily liquid with a characteristic smell. It is lighter than water and insoluble in it. It is a mixture of hydrocarbons (solid, liquid as well as gaseous) formed by decomposition of animal and plant remains inside the earth. Petroleum occurs in large quantities in the depths of earth between certain sedimentary layers. Huge quantities of gas (called Natural Gas, largely a mixture of hydrocarbons) also occur along with petroleum under the earth.

Petroleum production—national efforts: India has made great progress in oil exploration and mining since independence. For example, during 1950-51 the indigenous crude oil production was 2.5 lakh tonnes against consumption of 34 lakh tonnes. This was raised to crude oil production of 211 lakh tonnes against a consumption of about 347 lakh tonnes by 1982-83. With increase in the production of crude oil, the production of associated natural gas has also gone up, e.g., 24,530 lakh cubic metres in 1982-83 and 28,273 lakh cubic metres in 1983-84.

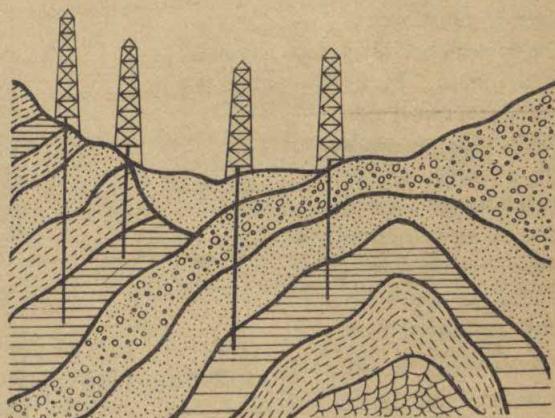


Fig. 11.5 Oil bearing rocks

The petroleum industry in India is divided into three broad segments: (1) oil exploration and production, (2) refining and marketing and, (3) petrochemical and downstream units. There are two principal organisations for exploration and production: Oil and Natural Gas Commission (ONGC) is the main government agency set up in 1956 for exploration and production of oil both from on-shore and off-shore areas of the country. Its significantly recent achievement is the production of oil from Bombay High. The other organisation engaged in exploration and production is Oil India Limited (OIL) set up by the government in 1981. The activity of this organisation was earlier limited to the eastern region of our country, but recently extended to Mahanadi basin and parts of Rajasthan.

In 1964, the Government of India set up Indian Oil Corporation (IOC) Ltd. for refining and marketing of petroleum and its products. The IOC has three main divisions namely, (1) Refineries and Pipelines Division, (2) Marketing Division, and (3) Assam Oil Division. About 61.5 per cent of the total industry sales (of petroleum products) was done through IOC in 1982-83.

The third segment, comprising petrochemical industry is of comparatively recent origin in our country. A large petrochemical complex, namely, Indian Petrochemical Corporation Ltd. was set up during 1974-78 at Vadodara (Gujarat). Its turnover during 1983-84 was worth about Rs. 468 crores.

Petroleum is obtained by drilling holes into the earth's crust where the presence of oil is anticipated. Many wells yield only gas. Hundreds of wells may have to be drilled and tested before an economically viable one is found to work for the production of oil. Some of the places in our country where oil is being produced are: Ankleshwar and Kalol in Gujarat. Rudrasagar and Lakwa in Assam, and Bombay High (off-shore area).

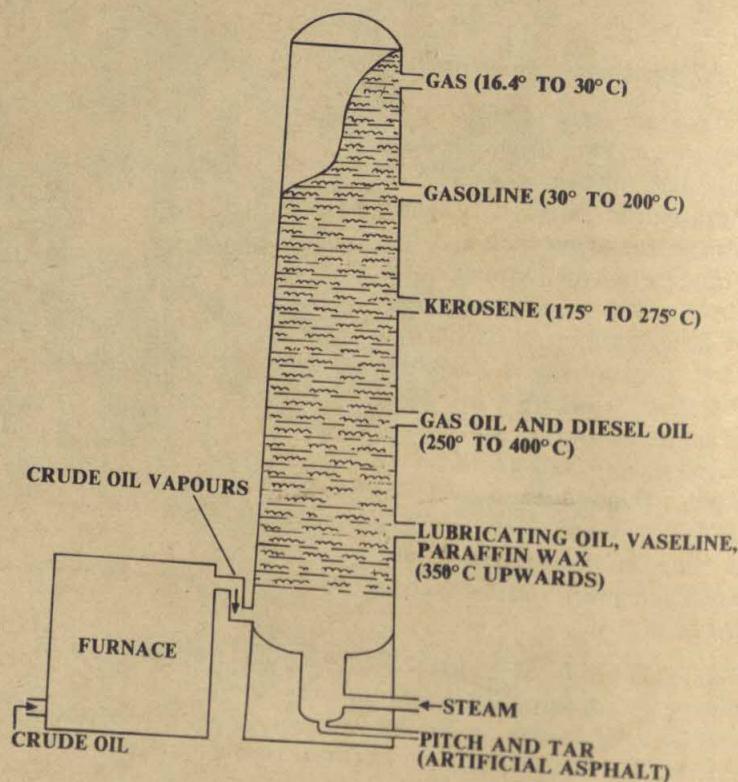


Fig. 11.6 Fractional distillation of petroleum

Refining of petroleum: Petroleum or crude oil is too complex a mixture of substances to be put to use directly. As drawn out from earth it is also mixed with water and earth particles. Therefore it needs to be separated into constituents that can be put to specific uses. This process of separation is called *refining*. Refining of petroleum is done by fractional distillation.

In simple distillation, the vapours of the boiling liquid are directly condensed. In fractional distillation, the vapours are allowed to rise through a packed column in which the higher boiling liquids condense whereas the vapours of lower boiling liquids rise further. Fractional distillation is an efficient method for separation of components of a liquid mixture like petroleum (Fig. 11.6).

Petroleum is heated to above 400°C and the vapours are passed from bottom upwards in a fractionating column. Fractions condensing at different boiling ranges are collected separately. Study the table giving names of some important fractions, their boiling range, molecular composition, and uses.

TABLE 11.3
Fractions from refining of petroleum and their uses

Sl. No.	Name of the fraction	Boiling point—range of constituents	Molecular composition (number of atoms)	Uses
1.	Gas	$16.4^{\circ}\text{C} - 30^{\circ}\text{C}$	C_1 to C_7	Gaseous fuel, production of carbon black, hydrogen, or gasoline (by polymerization)
2.	Gasoline	$30^{\circ}\text{C} - 200^{\circ}\text{C}$	C_5 to C_{12}	Motor fuel, solvent, dry cleaning, making petrol gas.
3.	Kerosene	$175^{\circ}\text{C} - 275^{\circ}\text{C}$	C_{12} to C_{16}	Household fuel for heating and lighting, making oil gas.
4.	Gas oil and diesel oil	$250^{\circ}\text{C} - 400^{\circ}\text{C}$	C_{15} to C_{18}	Furnace fuel, fuel for diesel engines, cracking.
5.	Lubricating oil, vaseline, praffin wax	350° C and above.	C_{16} upwards	Lubrication, vaseline, grease, wax for lubrication, vaseline, grease, wax for candle manufacture.

There are about a dozen refineries in our country with a total capacity of handling about four crore tonnes of crude oil. The oldest one is at Digboi (Assam), established in 1901. Some other refineries are located at Bombay, Visakhapatnam, Guwahati, Barauni, Koyali, Cochin, Madras, Haldia and Mathura. It would be interesting for you to locate these places in a geographical map of India.

The figure on p. 194 shows diagrammatically the products obtained from petroleum. The fractions of petroleum are used as raw materials for the large-scale production of a number of substances collectively known as petrochemicals.

11.3.3 Fuels—solid, liquid and gaseous

Some common fuels: Things are required to be heated both at home and in industry. Most of this heat is obtained by burning things like wood, coal, kerosene, alcohol, petrol and gases.

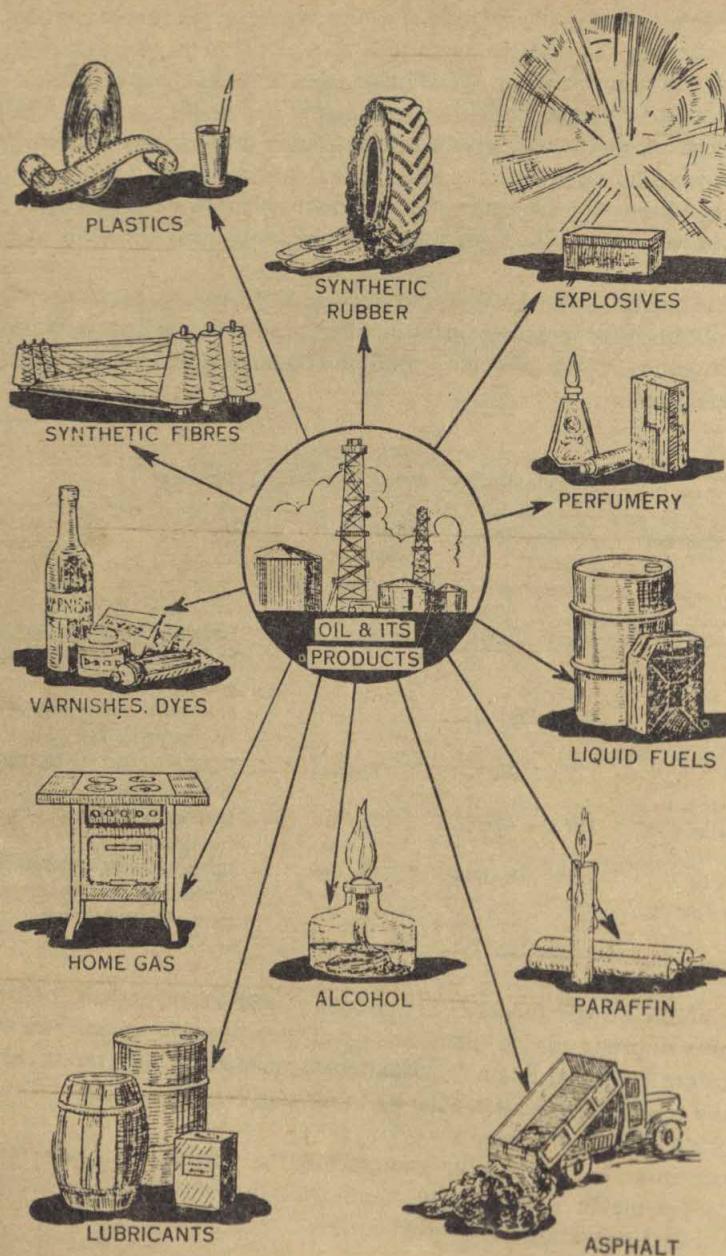


Fig. 11.7 Petroleum and its products

The material that is burnt for producing heat energy is known as fuel. Study the following table for names of some common fuels.

TABLE 11.4
Some Fuels

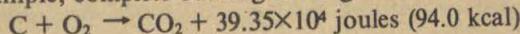
Solid fuels	Liquid fuels	Gaseous fuels
Coal	Kerosene oil	Natural gas, Liquefied Petroleum Gas (L.P.G.)
Coke	Petrol	Petrol gas, Gobar gas, Coal gas
Wood	Diesel	Water gas (H_2+CO)
Charcoal	Alcohol	Producer gas (N_2+CO)
Wax (Paraffin)	Liquefied hydrogen	Acetylene, Hydrogen (gas)

Liquefied petroleum gas (LPG): LPG is commonly used for domestic heating purposes. It is supplied in gas cylinders that need to be replaced when its fuel contents are consumed. The fuel supplied in gas cylinders contains a mixture of liquefied butane and iso-butane under pressure. As pressure is released, the highly volatile liquid fuel in the cylinder evaporates. The gaseous mixture starts going into the burner of attached stove or oven. Here it is ignited and the blue flame is used for cooking, etc.

The gas cylinder should be used with extreme care. There are obvious reasons for it. The fuel is highly volatile and gaseous under ordinary atmospheric conditions, so the danger of leakage from any crack in the worn-out rubber tubing, used for connection, or other loose connections is quite serious. Moreover, the fuel in LPG is highly combustible and forms an explosive mixture with air. So, any leakage followed by mixing with air can cause a severe explosion by just ignition of one match-stick. In order to make gas leakage easily detectable, some strongly smelling substance is added to LPG. Before igniting the match-stick we should be sure that there is no such smell near the gas cylinder or in the kitchen.

There are some precautions in respect of igniting the gas stove flame and putting it off. When putting off the stove, first the stopcock of the cylinder should be closed and then the cock of the oven should be closed. Similarly, when the stove is to be lighted, first the gas cylinder cock is opened and then the cock of the oven turned on to release the gas which is then ignited.

Calorific value of a fuel: When a given mass of fuel burns, a definite amount of heat is evolved. For example, complete burning of 12 g carbon would release 39.35×10^4 joules of heat.



Calorific value of a fuel is the amount of heat obtained by burning one gram of that fuel. It is generally expressed in calories (1 calorie = 4.1868 joules).

11.3.4 Principles and methods for extinguishing fires

For producing fires, there are three essential requirements, namely, (i) a combustible substance, (ii) supply of air (i.e., oxygen) which is a supporter of combustion, and (iii) a suitable temperature (i.e., the ignition point of the combustible substance).

Fires can be extinguished by removing any one or more of these factors. For example, all combustible substances in the vicinity of fire may be removed. The fire, in a way, would

automatically go out after some time because of lack of the fuel. It would be like putting out fire by 'starving' it. A second approach of extinguishing fires may be based on cutting off the supply of air to the fire. For example, the fire, i.e., the burning material is enveloped by something that does not burn. The fire goes off because supply of fresh air to support combustion is cut off. The third approach may be to cool the burning material to a temperature below the ignition point¹. You may recall as examples of this approach the quenching of burning firewood or coal by pouring water over them.

Whenever a fire breaks out, the fire brigade throws water on it under high pressure to cool the burning material to a temperature below the ignition point. The soda-acid fire extinguisher works on this principle (Fig. 11.8). However oil fires such as at airports or petrol pumps should not be extinguished by throwing water. Why?

When water is thrown over oil fires, water being heavier than oil, settles down. The oil therefore continues to burn. In such cases the foam type fire extinguisher is used. The foam containing carbon dioxide, formed by the action between the acid and aqueous sodium bicarbonate solution is stabilised, by the addition of Turkey red oil. This foam coming out with great pressure covers the entire surface of burning oil. The supply of air is thus cut off and the fire is extinguished.

For extinguishing fires caused by electricity, we cannot use extinguishers based on the use of water because this would result in electrocution of the people involved. A fire extinguisher based on the use of carbon tetrachloride is used in such cases. The carbon tetrachloride liquid vaporises on coming in contact with the burning material. Since these vapours are heavier than air, they settle on the burning material and cut off the supply of air. There is an important precaution with the use of carbon tetrachloride fire extinguishers. They should not be operated in closed rooms because a highly poisonous gas, namely phosgene ($COCl_2$), may then be produced. It is advisable to cover mouth and nose with wet cloth to protect oneself from the effect of carbon tetrachloride (CCl_4) vapours.

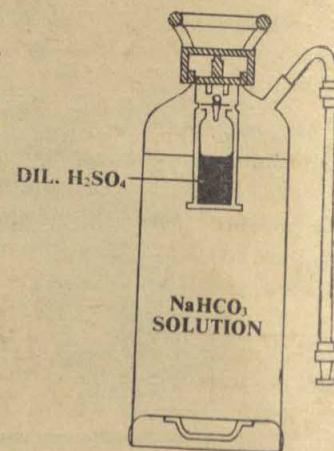


Fig. 11.8 Soda-acid fire extinguisher

11.4 SOME COMMON FERTILIZERS AND PESTICIDES

In our country agriculture is the largest occupation. With more than 80 per cent of our population living in villages it is natural that a very large percentage of our people should, directly or indirectly, live on agriculture as their occupation. Chemistry plays a very important role in the development of agriculture and in the production of more and better food.

11.4.1 Fertilizers and manures for supply of plant nutrients to soil

As crops grow and are then harvested the agricultural land suffers loss of certain elements, largely nitrogen, phosphorus and potassium, which are known as *primary nutrients*. Other

1. The lowest temperature which will cause combustion to start and spread through a combustible mixture is known as ignition temperature or ignition point.

nutrient elements essential for plant growth but required in lesser amounts are: calcium, magnesium and iron. Certain elements, called micro-nutrients, e.g., copper, manganese, cobalt, zinc and boron, are also essential for plant growth, but needed only in very small quantities.

Forty kg of corn contains about half-a-kilogram of nitrogen and lesser amount of other mineral nutrients. If these nutrients are not replaced, their supply in soil may become so poor that plant growth will be limited. The deficiency of essential elements in the soil is made good by the addition of manures and fertilizers to the soil. A manure is a natural substance obtained by the decomposition of animal excreta or plant residues. A chemical fertilizer is a salt or some other chemical substance, containing the necessary plant nutrients.

Some common fertilizers: Fertilizers having only one primary nutrient (i.e., N, P or K) are called single fertilizers. Examples are:

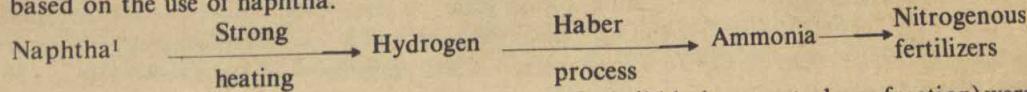
- (1) Nitrogenous fertilizers such as ammonium sulphate, ammonium nitrate, sodium nitrate, urea;
- (2) Phosphoric fertilizers such as superphosphate; and
- (3) Potassium fertilizers such as potassium chloride.

Fertilizers having more than one primary nutrients are known as mixed fertilizers. Depending on the nature of nutrients, these may be classified as NK, NP, PK or NPK type. For example, potassium nitrate (KNO_3) is a mixed fertilizer of NK type; ammonium hydrogen phosphate, $(NH_4)_2HPO_4$, also called Ammophos is of the NP type. Fertilizers of NPK type are known as complete fertilizers because they supply all the essential primary nutrients. Fertilizers are often marketed with special trade names, such as, 'Kissan Urea', 'Kissan Khad'.

As compared to fertilizers, the manures are not very rich in the plant nutrients (i.e., N, P, K). But they do provide to the soil abundant organic matter such as humus. This helps to improve both the physical and chemical properties of the soil. You have already studied in Class IX how the indiscriminate use of inorganic fertilizers leads to problem of soil pollution. Excessive and indiscriminate use of inorganic fertilizers is, therefore, avoided.

11.4.2 Fertilizer industry in India

It was in the Third Five Year Plan that this industry was given support in a big way by the government. In the beginning most of the capacity for fertilizer production in the country was based on the use of naphtha:



Later on, new plants based on the use of coal or fuel oil (the heavy petroleum fraction) were erected. In the context of the availability of large quantities of gas in our country (at Bombay High and other places), presently the stress is on the use of gas or coal, as the feed-stock. Use of fuel oil is now not permitted for the manufacture of fertilizers.

Increasing amount of chemical fertilizers are being manufactured in our country to meet the growing demand. There are more than sixty fertilizer factories of various sizes in the private and public sectors. Some of the main centres of fertilizer production are located at Sindri (Bihar), Alwaye (Kerala), Nangal (Punjab), Rourkela (Orissa), Gorakhpur (U.P.), Bombay (Maharashtra), Namrup (Assam), Durgapur (West Bengal), Cochin (Kerala), Madras, Talcher, Ramagundam (Tamil Nadu).

1. Naphtha is a petroleum or coal-tar distillation product used as a liquid fuel and solvent. It is more volatile than kerosene, but less than petrol.

11.4.3 Control of weeds and pests

Chemistry plays an important part in the control of weeds and pests as well. A weed is an unwanted plant that grows with a crop. Weeds take away a lot of nutrients added to the soil for promotion of the growth of crops. A good weed-killer should be cheap, effective and easy to apply in solution. It should not be harmful to man or animals.

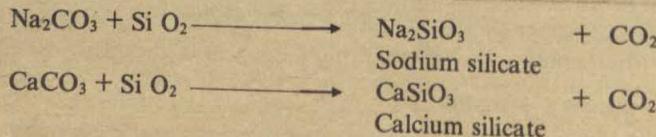
Pests include certain plants as well as animals, such as rats (a rodent) or locusts (an insect). The pests cause tremendous loss to crops. They are controlled by using chemicals in different forms, such as dusts, sprays, or as gas. Any substance, organic or inorganic, which is used to destroy or inhibit the action of plant or animal pests, is known as pesticide. Pesticides include such chemicals as insecticides, herbicides, rodenticides, miticides, etc. Almost all pesticides are toxic to man to a greater or lesser degree. Some common chemicals used for pest control are: Dichloro-diphenyl-trichloroethane (or simply DDT) and Benzene hexachloride (or simply BHC) or gammexane, zinc phosphide, methylparathion. Use of DDT has been banned in many countries because of its harmful ecological effects.

11.5 GLASS AND CEMENT

11.5.1 Glass

As far back as 3000 BC, the Egyptians were familiar with a glass-like material. However, till 1900 A.D. there was not much progress in the art of making glass. A tremendous progress has since been made in the production and use of different types of glass.

Manufacture of glass: Glass is mostly produced by heating to about 1400° C a mixture of silica (Si O_2), soda ash ($\text{Na}_2 \text{CO}_3$) and lime stone (Ca CO_3) in a furnace.



At 1400° C, the excess of silica dissolves in the molten mass of sodium and calcium silicates. This liquid mass upon rapid cooling forms glass corresponding approximately to this composition: (Na_2SiO_3 , CaSiO_3 , 4SiO_2). This is soft glass and is used for making bottles, light bulbs, etc. If potassium carbonate is used instead of sodium carbonate, the product formed is hard glass. This is used for making laboratory glassware. Often we need special type of glasses with certain specific properties, e.g., with colour or heat-resistance. New properties are generated in glass by addition of other substances to the above mentioned three general components.

11.5.2 Cement

One of the most important building materials is 'portland cement', or simply called as cement. It is mainly a mixture of aluminates and silicates of calcium. Early in the 19th century it was discovered that cement, upon being mixed with water and allowed to stand for some time, sets to a hard mass which resembled Portland rocks. Hence, the material was called Portland cement.

Manufacture of cement: Cement is prepared by heating a fine mixture of limestone and clay. For heating, the fine mixture is converted first into a slurry by adding a little water. In some manufacturing plants, the dry mixture of limestone and clay is heated. A rotary kiln, about 50 metres long and 2 to 6 metres in diameter is used for heating (Fig. 11.9). Hot gases obtained by burning powdered coal, oil, or gaseous fuel are passed through the kiln from bottom upwards. Thus, a temperature of about 1500°C to 1600°C is maintained. The product, known as clinkers, is cooled to atmospheric temperature, mixed with a little gypsum and then powdered.

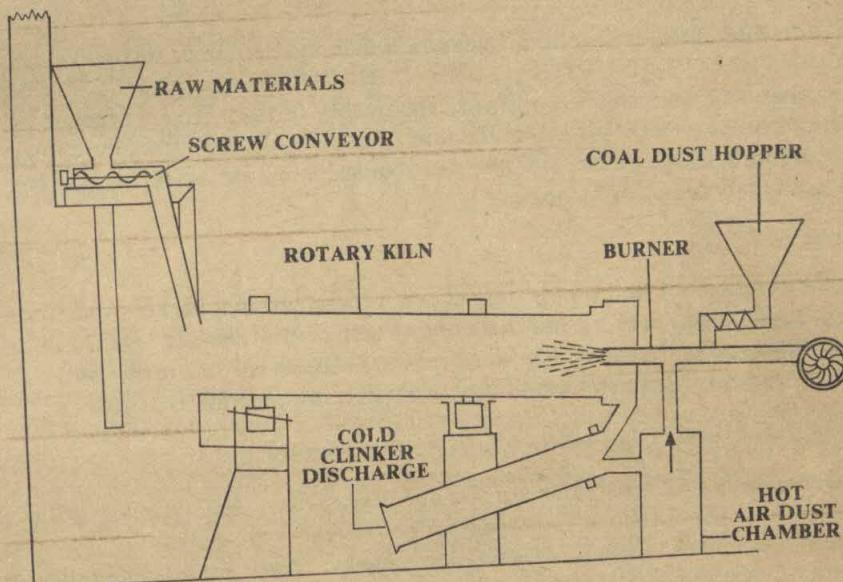


Fig. 11.9 Diagram of Rotary kiln for manufacture of cement

Manufacture of cement in our country was first started in Madras in 1904. At present there are 89 cement factories in our country with total installed capacity of 369 lakh tonnes per annum. However, the production of cement in 1983-84 was about 270 lakh tonnes. In 1950-51, the production of cement was only 29 lakh tonnes.

Composition of cement: The average composition of cement is as given below:

Calcium Oxide	(CaO) - 62%
Silica	(SiO_2) - 22%
Alumina	(Al_2O_3) - 7%
Other oxides	- 9%

A mixture of cement and sand in the ratio of 1:3 and mixed with water to form a slurry is called mortar. It is used for plastering walls. For flooring and roofing, to this mixture are also added small pieces of stone and some coarse sand. With a framework of iron bars inside as a support (say for the roof or beams) the product is known as 'reinforced cement concrete' (RCC). It is a very strong material for construction, and used for making lintels, roofs, pillars, etc.

11.6 SOAPS AND SYNTHETIC DETERGENTS

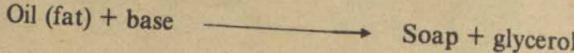
Any substance that reduces the surface tension¹ of water can be called a detergent. It is specifically a surface active agent² which concentrates at oil-water interfaces. It exerts an emulsifying action (i.e., allows greasy or oily impurities to mix well with water) that aids in removing soils. Detergents are widely used for laundry, textile manufacture, sanitation, shaving soaps, shampoos, etc.

11.6.1 Soaps

The older still widely used detergents are soaps. Commonly used soaps are sodium salts of fatty acids, such as, oleic ($C_{17}H_{33}COOH$), stearic ($C_{17}H_{35}COOH$) and palmitic ($C_{15}H_{31}COOH$) which are obtained from plants or animals. The quality of soap largely depends on the raw materials used or the process of its manufacture. The soaps obtained from the above acids are known as sodium oleate, sodium stearate and sodium palmitate, respectively. Soap may be prepared in the laboratory or at home.

Experiment 11.2

Take about 10 ml cotton seed oil (or linseed or soyabean oil) in a beaker. Add 10 ml of 40% sodium hydroxide solution to it. Boil this mixture with continuous stirring till a thick paste is produced. Some hardening agents like water glass, or sodium carbonate may also be added to the paste to harden the soap. A simple way to express the reaction is as follows:



Add some sodium chloride to precipitate out all soap from the aqueous solution. Use this soap to wash your handkerchief. Do you find it effective?

Modern commercial soaps, besides the genuine soap also contain disinfectants, medicaments of various kinds and bleaching materials. These materials make them more suitable for their specific use.

11.6.2 Synthetic detergents

Soaps are relatively weak in their action as detergents. Synthetic detergents are very much different in chemical nature from ordinary soap. If unsaturated hydrocarbons of the ethylene type (Alkenes) containing between ten to eighteen carbon atoms are allowed to react with sulphuric acid, some kind of organic acids (known as sulphonic acid) are formed. The sodium salts of these acids have a remarkable property. They enhance moistening of the cloth, etc., thus promoting the cleaning action. Such compounds are known as synthetic detergents. They do not form any insoluble compound with calcium or magnesium ions, and therefore, are advantageously used even with hard water.

1. Surface tension is the tendency of the surface of a liquid to occupy the smallest possible area. Liquids with high surface tension do not spread out well when applied to any surface.
2. Surface-active agents are substances, which upon being added to a liquid influence its properties like the capacity of the liquid to spread out on a surface. Usually they decrease surface tension and increase the spreading capacity.

Experiment 11.3

Take two beakers and pour into each about 100 ml of hard water. In case hard water is not available, prepare it by dissolving some calcium sulphate or magnesium chloride in ordinary tap water. Add a small piece of washing soap to one beaker, and about an equal amount of any synthetic detergent to the other beaker. Stir well. What difference do you observe in respect of lather formation in the two cases? Use the contents of the two beakers separately to wash pieces of cloth. Which of them works better? Why?

The raw materials for preparing synthetic detergents are obtained from petroleum industry. The raw materials for making soap are often vegetable oils which are scarce, because they are also used as food articles in large quantities. Thus manufacture of synthetic detergents as soap substitutes helps us to save vegetable oils for human consumption. However, synthetic detergents also create an environmental problem. Some of the synthetic detergents are not biodegradable, i.e., are not decomposed by micro-organism. In this way they create a water pollution problem.

11.7 CHEMICAL INDUSTRY IN INDIA

Chemical industry plays a pivotal role in the Indian economy. This is so because organic and inorganic chemicals provide the basic building blocks for the manufacture of several downstream products such as drugs, dye-stuffs, pesticides, plastics, paints, perfumery, etc.

Major inorganic chemicals like soda ash, caustic soda, carbon black, calcium carbide, red phosphorus, potassium chloride are manufactured within the country in sufficient amounts to meet our needs. Basic organic chemicals like phenol, methanol, formaldehyde, acetone, acetic acid are also manufactured in substantial quantities. Important sources for these chemicals are: alcohol (from molasses which is a by-product of cane sugar industry), benzene (a by-product of coke-oven industry) and petroleum.

EXERCISES

1. Write an account of the importance of chemistry in our everyday life.
2. In what ways has chemistry helped man to get the various comforts of life?
3. The basic needs of life are food, shelter and clothing. Discuss the vital role played by chemistry in meeting these needs.
4. Give two examples for each of the following:
 - (i) Synthetic rubber
 - (ii) Artificial fibres
5. Why are cotton clothes being replaced by terylene clothes?
6. Give the characteristics of nylon fibres.
7. How will you distinguish between:
 - wool, silk, cotton and artificial fibres?



8. Write down the uses of nylon fibres. What properties of nylon make it specially suitable for the purpose?
9. What are the advantages when terylene is mixed with wool to prepare cloth?
10. Write short notes on:
 - (i) Glass
 - (ii) Cement
11. Name the three requirements for producing a fire.
12. What is the name given to 'the minimum temperature' to which a substance should be heated before it can catch fire?
13. Why are the fires in oil tanks not extinguished by pouring of water over them?
14. Describe in short the principle of extinguishing fires in the electrical equipment or circuit. Why should water be not used in these cases?
15. Write names and formulae of at least two compounds used as fertilizers for the supply of:
 - (i) Nitrogen
 - (ii) Phosphorus
 - (iii) Potassium
16. What are pesticides? Give two examples.
17. Describe in brief the role of chemistry in agriculture.
18. What are the different fractions obtained by refining of petroleum? State their respective uses.
19. What is petroleum? Where does it occur?
20. Name two places in our country where crude oil is being produced. Name two places where refineries are located.
21. Describe how natural rubber is obtained from the latex of a rubber tree. Discuss what is done to improve the properties of natural rubber.
22. Compare the properties of raw natural rubber with those of vulcanised natural rubber.
23. Name the products obtained by dry distillation of coal. What for is the product 'coke' used?
24. Name two gaseous fuels. Also name their sources.

UNIT 12

Nuclear Reactions as a Source of Energy

Introduction

So far we have studied *chemical changes* involving electrons in the outermost shell of an atom. In such a change, energy change is small and is known as *chemical energy*. The energy change is due to bond breaking and bond formation that occur during the reaction. In such a change nucleus remains unaffected. However, there is another type of reaction in which nucleus of an atom undergoes a change involving release of tremendous amount of energy. Such reactions are called *nuclear reactions*. Since these nuclear reactions are potential sources of energy, we shall study about them briefly in the present Unit.

12.1 Renewable and non-renewable sources of energy

Today we are in an era of science and technology, and human progress depends on it. In fact, the standard of living is now-a-days related to the energy consumed by an average person. During the last two decades there has been industrialisation on a large scale, both in developing and developed countries. Due to this heavy consumption an energy crisis in the world energy market has occurred. Efforts are, therefore, being made to solve this crisis. Let us see what the sources of energy are and how we can control them so that energy is made available adequately for our consumption and also for the times to come.

It is remarkable to note that about 80% of the world energy comes from fossil fuels (petroleum and coal), 20% from dung and vegetable waste and 1% from water power (mainly hydropower) and minor amount from nuclear, solar, geothermal¹ and wind power. These energy sources can be broadly divided into two major categories: (i) Renewable (non-conventional) and, (ii) Non-renewable (conventional). Renewable sources include plant, food

1. Power generated from heat of earth.

and feed, wood, fuel, vegetable refuse, falling water, geothermal power, etc. These sources are produced continuously in nature and are essentially inexhaustible, at least during the existence of human society. Crude oil, coal and lignite, natural gas, uranium, etc. fall in the category of non-renewable energy sources. These energy sources are accumulated over the ages and are not quickly replaceable when they are exhausted.

It is a well-known fact that our non-renewable sources of energy (crude oil, coal, etc.), which are our major sources, can last only for a limited period of time. Therefore, it is necessary that renewable energy sources should provide a significant proportion of our energy needs.

A global effort is being made to tap energy from the non-conventional sources. In our country, in the last decade, a lot of research work has been done on solar energy, wind energy and tidal energy. Solar energy, obtainable in a number of ways, in the form of heat, electricity (solar cells) or chemical energy, represents an immense potential for India.

One of the potential sources of energy is nuclear energy which is obtained as a result of nuclear reactions. In this Unit, you will be able to know how nuclear energy can be utilised in generation of power and for other peaceful purposes.

12.2 Radioactivity

Before going into details of nuclear energy, it will be quite relevant to know something about nuclear changes/reactions. In 1896, Henri Bacquerel found that photographic plates when left in contact with uranium salts in dark got darkened. This darkening is like the one when these plates are exposed to x-rays. Bacquerel suggested that uranium spontaneously emits a penetrating form of radiation that is responsible for darkening of photographic plates. The experiments were repeated with thorium element and the same results were obtained with photographic plate. *The phenomenon of emitting radiations by some elements (such as uranium and thorium) was given the name radioactivity and the elements were called radioactive elements.* In an enthusiastic and dedicated study of the phenomenon, Marie Curie with her husband Pierre Curie discovered two new elements, polonium and radium, from the ore of uranium, both more radioactive than uranium. At present, over fifty *naturally occurring* radio isotopes are known.

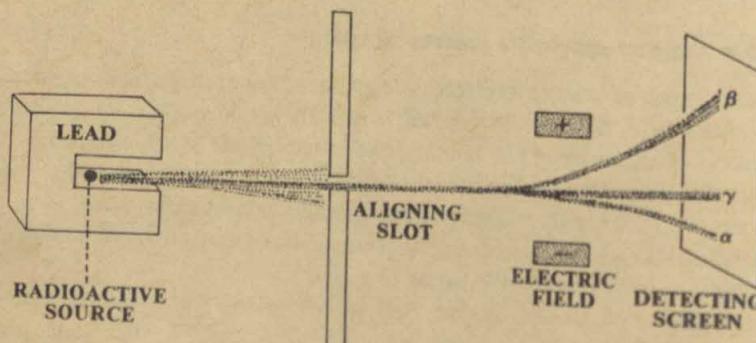


Fig. 12.1 Nature of α , β and γ rays—three kinds of radiations behave differently in the presence of an electric field.

12.3 Nature of radiation

If the radiation from various radioactive substances are passed between the two poles of a strong electrostatic field (at the right angles to the directions of field), three major kinds of radiation, with entirely different type of behaviour, are observed (as shown in Figure 12.1). These are named as alpha particles (α -particles), beta-particles (β -particles) and gamma ray (γ -ray). In a radioactive change, a nucleus usually loses just one particle, alpha or beta, and the particle frequently is accompanied by a gamma ray. During the process of radiation an unstable nucleus gives out energy and attains a more stable form. Thus, the emitted particles and rays are carriers of excess energy.

1. *Alpha (α) particles*: These particles are composed of two protons and two neutrons, and are identical to the nucleus of a helium atom. Thus each particle has a mass of about 4 atomic mass unit and a positive charge of two electronic unit. An α - particle is represented by the symbol ${}^4_2\text{He}$. They are the most massive of the three radiations, but the slowest and the least penetrating (Fig. 12.2). They can travel to a maximum of 10 per cent of the speed of light and can be stopped by a piece of thin paper. Therefore, penetration of α -particles into living system from outside is small. These particles can damage the tissues only when they are brought into intimate contact with internal tissues and organs.

2. *Beta (β) particles*: This particle is simply an electron emitted by the nucleus, but its energy

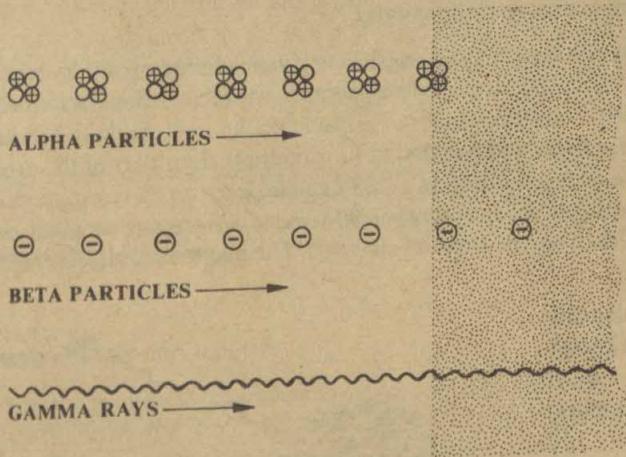


Fig. 12.2 The penetrating power of the three kinds of radioactivity: Alpha particles penetrate the least, gamma rays the most.

and velocity are so high that it can be very destructive. It may travel upto 90 per cent of the speed of light. These particles can penetrate into the tissues to the extent of a centimeter or slightly more.

3. *Gamma (γ) rays*: The gamma ray is a radiation of distinctly different character. It is a form of electromagnetic radiation like visible light itself, and travels with the same velocity. Gamma rays, like x-rays, have a much shorter wavelength than light, a far greater energy and a higher penetrating power.

The properties of various forms of radiations are summarised in Table 12.1.

TABLE 12.1

Type	Symbol	Mass Number	Charge	Approx. tissue penetration (cm)	Make up
Alpha particles	$\alpha, {}^4_2 \text{He}$	4	+ 2	0.01	2 proton 2 neutron
Beta particles	$\beta, {}^0_{-1} \beta$ or ${}^0_{-1} \text{e.}$	0	- 1	1	1 electron
Gamma-ray	γ	0	0	100	Electromagnetic radiation

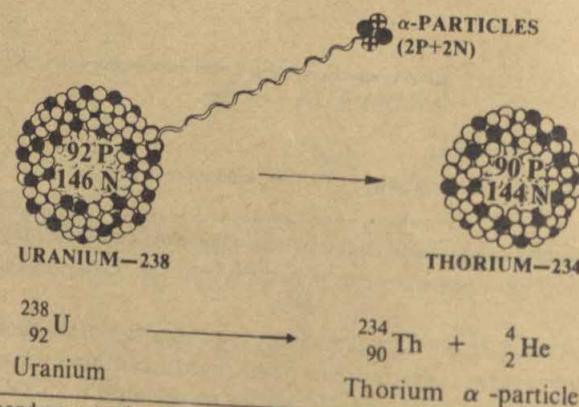
(Some other types of particles such as neutron, proton and positron, which are given in certain cases, are represented by ${}^1_0 \text{n}$, ${}^1_1 \text{H}$ and ${}^0_{+1} \text{e}$ respectively).

As can be appreciated now, the loss of α - and β -particles will change the atomic number of the radioactive element. Thus, new elements will be formed as a result of nuclear reaction. These reactions are represented by *nuclear equations* similar to chemical equations.

12.4 Nuclear changes during radioactivity

The two most common types of radioactive decay are characterised by emission of α - and β -particles. As stated earlier, the α -particle is identical with the nucleus of the helium—4 atom, ${}^4_2 \text{He}$. Consequently, when a nucleus emits an α -particle, the new nucleus has an atomic number that is two less and a mass number that is four unit less than that of the original nucleus. For example, the alpha decay of uranium—238 nuclide¹ leads to the formation of a new element, thorium—234, which has atomic number 90 (two less from the original element) and mass number 234 (four less from the original element). The nuclear reaction is represented as below:

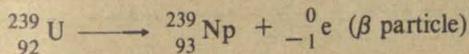
Here, while balancing a nuclear equation always remember that both charge (atomic number) and mass number are conserved. Thus, the sums of the atomic number and of mass number before and after a nuclear reaction must be the same.



¹ When a nucleus of specific atomic number and mass number is considered, the nuclear scientists refer to a nucleus as a *nuclide*. For example, nucleus of uranium having atomic number 92 and mass number 238 is expressed as ${}^{238}_{92} \text{U}$. Nuclide and isotope for all practical purposes convey the same meaning.

You are aware that all the isotopes undergo the same type of chemical change in view of there being the same number of valence electrons in their outermost shells. This is not true in case of nuclear changes. A nucleus of a particular isotope may undergo one type of change whereas nucleus of another isotope may undergo an entirely different type of change. (You will find this in case of U-235 and U-238). It would also be interesting to note that a radioactive (nuclear) change is irreversible (unlike a chemical change) and is independent of factors that usually affect chemical changes, such as temperature and pressure.

Negative beta-particles are identical with electrons. When a nucleus emits a beta-particle, the atomic number of the new nucleus is one greater than that of the decaying nucleus but mass numbers are the same. For example, the beta decay of the unanium-239 nuclide yields neptunium-239.



Here we can see that atomic number has increased by one and mass number remains unaffected.

The gamma rays are usually emitted along with alpha or beta particles, though some nuclei emit gamma radiation without an accompanying particle. These rays are emitted as a result of rearrangements of the neutrons and protons in a nucleus. *Neither the mass number nor the atomic number is changed by gamma ray emission.*

Here it would be important to remember that radioactivity is the property of the atomic nucleus, and therefore, remains as such even when a radioactive element forms a compound. Carbon-dioxide (CO_2) prepared out of radioactive carbon will exhibit radioactive behaviour. This property is very important and is utilised in investigating certain reaction mechanisms.

12.5 Rate of radioactive decay and half life

The rate of a radioactive change is a characteristic property of a nucleus and is measured in terms of *half life*. Half life is the time required for the decay of one-half of the atoms (radioactive nuclides) present in any given mass of a radioactive substance. After a period of half life radioactivity of the sample will be reduced to half. *Thus, half life of a radioactive nuclide is the time required for a sample of that nuclide to become half as radioactive as it was at any given point of time.* For example, the half life of nuclide I-131 is 8 days. This means that, for 1 mole of I-131 nuclide, half of it or 0.50 mole will have decayed in 8 days and half of the 0.50 mole remaining, or 0.25 will have decayed in another 8 days.

Short half lives indicate rapid decay rates and long half lives indicate slow decay rates of radioactive isotopes.

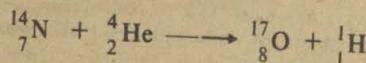
Half lives vary from billions of years for some radio-isotopes (nuclide) to infinitesimal fractions of a second. Half life of a few common radio-isotopes is provided in Table 12.2.

TABLE 12.2

Elements	Isotopes	Half life	Elements	Isotopes	Half life
Uranium	$^{238}_{92}\text{U}$	4.51×10^9 years	Iron	$^{59}_{26}\text{Fe}$	44.3 days
Radium	$^{220}_{88}\text{Ra}$	15.9×10^2 years	Phosphorus	$^{32}_{15}\text{P}$	14.3 days
Carbon	$^{14}_{6}\text{C}$	5.73×10^3 years	Iodine	$^{131}_{53}\text{I}$	8.0 days
Cobalt	$^{60}_{27}\text{Co}$	5.27×10^5 years	Polonium	$^{214}_{84}\text{Po}$	1.5×10^{-4} seconds

12.6 Artificial transmutation of elements and preparation of radioactive isotopes

We have just seen how a naturally occurring radioactive element gets changed into a new element. This of course aroused a curiosity in scientists whether artificial transmutation (change) of elements is possible or not as was conceived by alchemists¹. It was in 1919 that such a dream was partially realised by Rutherford. He observed that when a stream of alpha particles is sent into a container of nitrogen gas, nitrogen-14 is changed into oxygen-17. In this process, protons are given out:



Thus, although Rutherford could not convert base metals into gold but he was able to turn one element into another. Now it has become possible to bring about transmutation of many more stable elements by bombarding with accelerated particles such as alpha particles, protons, neutrons, deuterons and some heavier nuclei.

Here it is worth noting that new isotope $^{17}_8\text{O}$ obtained in the above reaction is quite stable. In 1934, Frederic and Irene Juliet-Curie observed that when stable isotope of aluminium ($^{27}_{13}\text{Al}$) is bombarded with alpha particles, the resulting isotope of phosphorus is found to be radioactive.

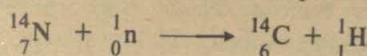


Here, radioactive isotope of phosphorus further decays in the stable isotope of silicon by giving out a positron ($^{+1}_0\text{e}$).

In this way, chemists have been able to produce hundreds of radio-isotopes normally not

¹ The transmutation of one element to another was coveted goal of Alchemists. They wanted to prepare precious metal, 'gold', from less precious metals (base metals).

found in nature. Radioactive isotopes¹ of carbon can be prepared as following:



Such artificially prepared radio-isotopes have found large number of uses in physico-chemical research, biology, medicine, industry and agriculture.

12.7 Uses of radioactive isotopes

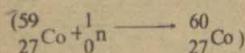
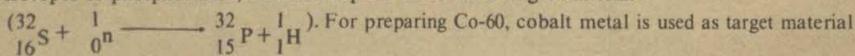
Radioactive isotopes find wide application in medicine, industry, agriculture and in many areas of scientific and technological interest.



12.3 (a) Use of radio-isotope in medicine. Scientists working in BARC laboratory (Courtesy: BARC, Bombay).

In medicine, radioactive isotopes can be used as *tracers* for diagnostic purposes. A tracer is a minute amount of a radio-isotope, added to a large amount of non-radioactive isotopes of elements. Usually, the tracer is part of a compound. In actual practice, a person drinks a liquid

¹ In actual practice, for preparing radioactive isotopes, a *target material* is selected and irradiated with neutrons. For example, for preparing C-14, nitrogen is taken in form of aluminium nitride (AlN). Similarly, for preparing radio-isotopes of phosphorus-32, element sulphur is used as a target material:



or receives an injection of a compound containing the tracer. The radioactive isotopes move through the body and can be followed by a radiation detecting device (like a Geiger Counter). For example, Arsenic - 74 (As - 74) is used to detect tumours. Na-24 is incorporated into salt, NaCl, and used to detect the presence of blood clots in the circulatory system. I - 131 is used in form of sodium iodide (NaI), to determine the activity of the thyroid gland. Co-60 is used in treatment of cancer. (When a gamma radiation emitted from Co-60 is directed at tumour, in many cases tumour stops growing or even shrinks). Gamma radiation is effective in sterilising medical products.

In industry, radio-isotopes are used to detect leak in water, oil and gas pipelines, to test wear and tear inside a car engine, to measure the thickness of a piece of a metal or rubber, and to check the level of soda in a can.

Fig. 12.4 (a) Use of radio-isotopes in industry. An engineer busy is detecting crack with the help of radio detector. (Courtesy: BARC, Bombay).

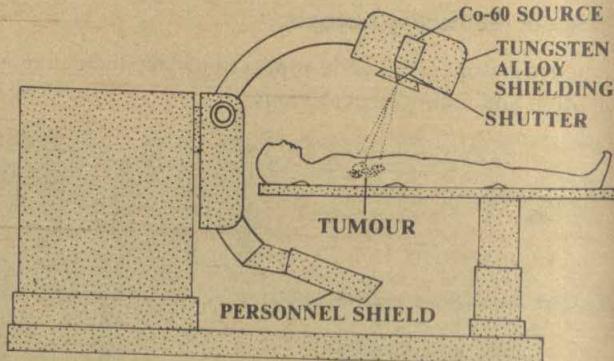


Fig. 12.3 (b) Use of Co-60 in destroying tumour.



In agriculture, the use of radioactive phosphorus in fertilizers has revealed how plants receive the phosphorus necessary for their growth. This has led to the improvement of

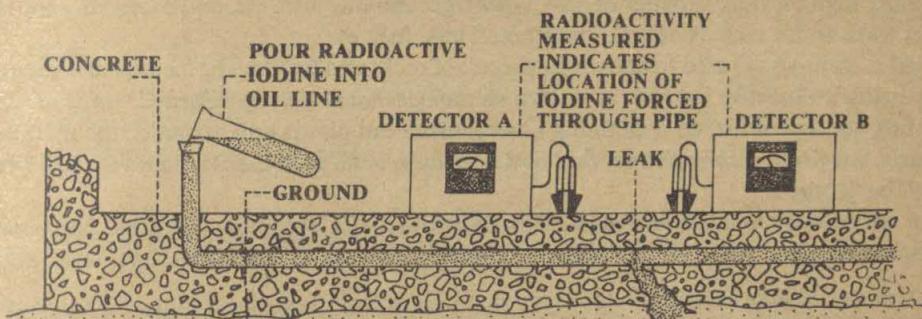


Fig. 12.4 (b) Use of radio-isotopes in detecting leak in oil pipe



Fig. 12.5 Use of isotopes in agriculture (courtesy: BARC, Bombay)

fertilizers. Radiations from radio-isotopes are being tried out for disinfecting food grains, for developing high yielding varieties of rice, wheat, groundnut, jute, etc. and preserving for long periods food stuffs such as onions, potatoes, fruits, fish, etc.

Radio-isotopes are used to determine the age of rocks and fossils. The method of estimating age by using radioactive isotopes is known as *radiochemical dating*. When C - 14 is used for estimating the age of carbon-containing objects (like dead plants and animals), the method is popularly known as *carbon dating*. Age determination of all such cases is based on half life of radioactive isotopes.

In our country, Bhabha Atomic Research Centre (BARC) prepares more than 350 types of radioactive isotopes which are finding wide application in the various fields mentioned above.

Radiation and human health: We have seen that radioactivity finds wide application in various fields of human endeavour. But we should always remember that alpha particles, beta particles, gamma ray and some other type of radiation are injurious to human and other living organisms. A simple particle usually has sufficient energy to break one or more chemical bonds or to ionise a molecule in living tissues. Ions produced in this way are highly reactive chemically. They can disrupt cell membrane, reduce effectiveness of enzymes, or even damage genes and chromosomes. Therefore, while working on these radiation or using radio-isotopes one should take all the necessary precautions.

12.8 Energy liberation during nuclear changes

You have studied the law of conservation of matter (Lomonosoff, 1756) according to which matter can neither be created nor destroyed. In many of the chemical reactions the mass of the products and reactants have been found to be the same, supporting the law. A similar law was proposed for energy, i.e., energy can neither be created nor destroyed, but energy in one form can be changed to another. You are aware that when electricity passes through the filament of an electric bulb, the electrical energy is converted into heat and light energy. Similarly, the combustion of petrol in the cylinder of an engine converts chemical energy into heat and finally into mechanical energy. In 1905, Einstein stated that matter and energy are interconvertible, i.e., matter can be converted into energy and vice-versa. This very important contribution of Einstein provided a unified law of *conservation of matter and energy*. (This law states that matter and energy can be transformed into each other, but the sum total of the matter and energy of the universe can neither be increased nor decreased).

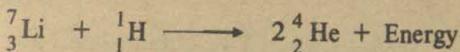
Einstein provided a relationship between mass and energy in the form of an equation:

$$E = mc^2$$

Where E is the energy, m is mass and c is the velocity of light.

During a nuclear reaction, an unstable nucleus is changed into a stable nucleus. Tremendous amount of energy is given out in such reactions. This energy results from conversion of a very small fraction of mass into energy. Energy can be calculated using Einstein equation.

Let us take a well-known reaction performed by Cockcroft and Walton (1932) which, for the first time, gave experimental evidence for the universal law of mass and energy.



Here, mass of ${}_{3}^{7}\text{Li} = 7.0160 \text{ amu}$

mass of ${}_{1}^{1}\text{H} = 1.0078 \text{ amu}$

Total mass of lithium and hydrogen atoms = 8.0238 amu

$$\text{Mass of product } 2 {}_{2}^{4}\text{He} = \frac{2 \times 4.0026 = 8.0052 \text{ amu}}{\text{Difference} = 0.0186 \text{ amu}}$$

If we consider masses in terms of gram, then difference is 0.0186 g or $1.86 \times 10^{-5} \text{ kg}$ / mole of lithium nuclide.

Therefore, energy corresponding to mass $1.86 \times 10^{-5} \text{ kg}$ will be

$$\begin{aligned} E &= mc^2 \\ &= (1.86 \times 10^{-5} \text{ kg}) \times (3 \times 10^8 \text{ ms}^{-1})^2 \quad \text{as } c = 3 \times 10^8 \text{ ms}^{-1} \\ &= 1.86 \times 10^{-5} \text{ kg} \times 9 \times 10^{16} \text{ m}^2\text{s}^{-2} \\ &= 167.4 \times 10^{10} \text{ kg m}^2\text{s}^{-2} \end{aligned}$$

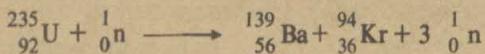
Since 1 Joule = $1 \text{ kg m}^2\text{s}^{-2}$

$$\text{Therefore, } E = 167.4 \times 10^{10} \text{ J} = 167.4 \times 10^7 \text{ kJ}$$

This gives us an idea about the release of tremendous amount of energy when such a small quantity of mass is used up in a reaction.

The particles making up the nucleus, the protons and neutrons are called *nucleons*. Energy required to keep the nucleus together in a nucleus is called *binding energy*. This energy is very high and is available due to conversion of mass into energy. In fact, this mass is especially named as *mass defect* which is the difference between the actual mass of a nucleus and the sum of the masses of its individual protons and neutrons. For example, mass of the helium nucleus ${}_{2}^{4}\text{He}$ is 4.0028 amu and sum of the masses of 2 neutrons and 2 protons is 4.0331 amu. Therefore, *mass defect* will be 0.0303 amu which, when converted into energy, gives $27.27 \times 10^8 \text{ kJ/mol}$ of He atom. Thus, binding energy in case of helium will be $27.27 \times 10^8 \text{ kJ/mol}$.

12.8.1 Nuclear fission: Scientists observed that bombarding elements with neutrons gives rise to a new element. Fermi (1934) bombarded U-235 using slow neutrons expecting that he would be producing a heavier element and, in fact, he thought that he had produced element of atomic number 93. In 1938, Hahn and Strassmann repeated Fermi's work and they obtained a number of known elements with atomic numbers between those of krypton (At No. 36) and barium (At No. 56) and a large amount of energy. This splitting of uranium nucleus into lighter nuclei was given the name 'fission'. Fermi mentioned that one of the possible reactions is:



During this fission a large amount of energy is released due to *mass loss*, i.e., the sum of the masses of the two fragments (Ba and Kr) and neutrons set free, is less than the sum of the masses of the reactants (U and one neutron). A tremendous amount of energy of the order of

19.66×10^9 kJ per mole of uranium atoms fissioning, is produced. Thus, if 1 gram of $^{235}_{92}\text{U}$ undergoes fission reaction, 8.36×10^7 kJ of energy is produced which will be obtained only after burning nearly 2.5 metric tons of pure carbon.

If we see the above equation of fission reaction, we find that each fission process emits more than one neutron. Since the fission of uranium nucleus is induced by a single neutron, the neutrons so produced induce other nuclei to split. Thus, three neutrons released in one fission reaction induce 3 fission reactions, which release 9 neutrons subsequently followed by 27 fissions, and so on. Since U-235 fission reaction is extremely rapid, this sequence sets up a *chain reaction* (Fig. 12.6) releasing tremendous amount of energy.

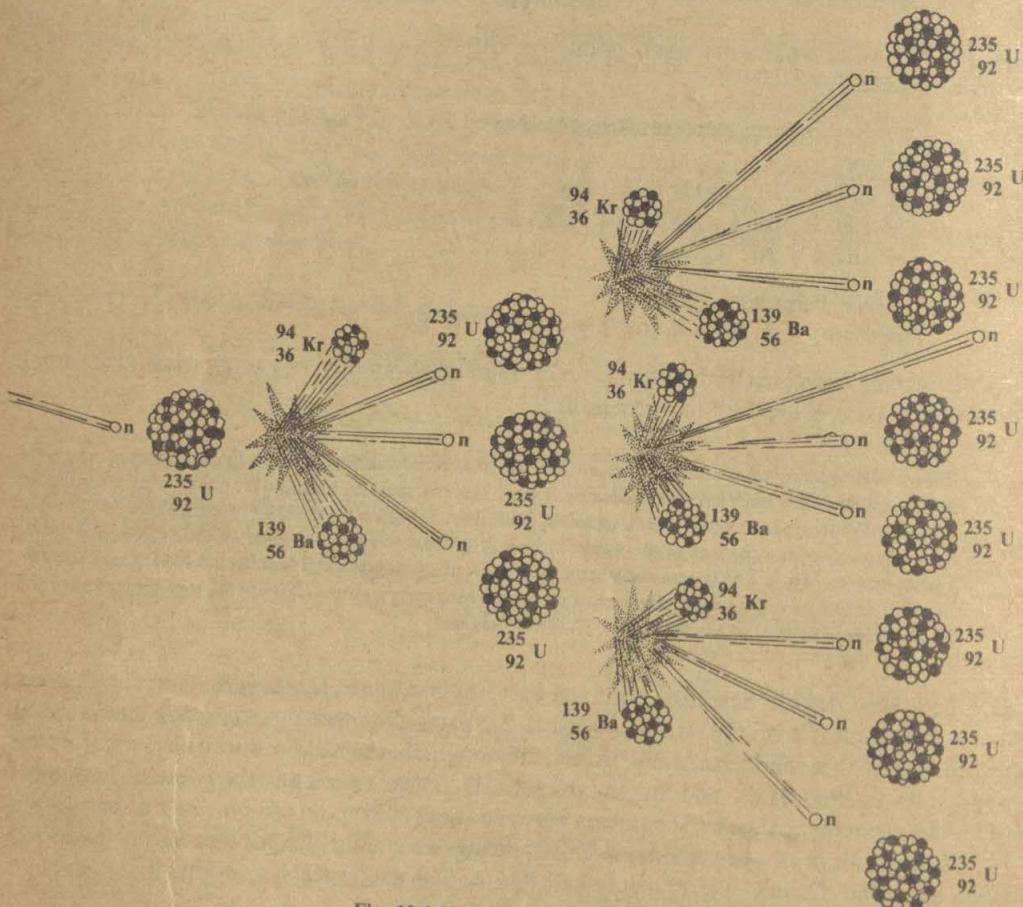


Fig. 12.6 Nuclear chain reaction

Based on fission chain reactions atomic bombs were ready by July 1945. The first atomic bomb was dropped on Hiroshima and three days later the second bomb was dropped on Nagasaki (Japan). This was the most tragic event in the history of man. Destruction caused by

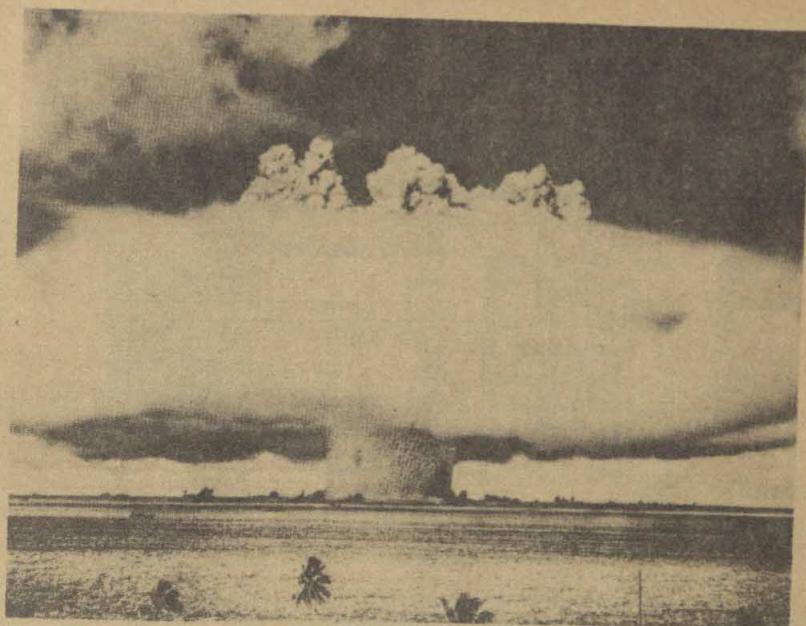
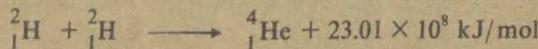


Fig. 12.7 Bomb explosion

these bombs ended World War II (Fig. 12.7 shows bomb testing).

Scientist and technologist also thought of constructive uses of these nuclear reactions by controlling explosive chain reaction during fission. They ultimately succeeded in designing a special machine in which a fission reaction could be carried out in a controlled way by limiting the number of neutrons. This machine is called *nuclear (atomic) reactor* (Fig. 12.8). In this machine graphite or cadmium rods or heavy water (D_2O) is used as moderator for slowing down the neutrons. Enriched uranium containing higher percentage, 2–3%, of U–235 is used as fuel. The heat produced from the reactor is used to convert water to steam, which is then used to drive turbine that generates electricity.

12.8.2 Nuclear fusion: Fusion reaction is quite opposite of nuclear fission. In such a reaction, light nuclei combine to form heavier nuclei. A typical fusion reaction is shown below:



Here, two deuterium nuclei (2_1H) are made to fuse together to form a helium nucleus. Energy of the order of 23.01×10^8 kJ is obtained when one mole of helium nucleus is formed.

Fusion reaction involves fusion of two positively charged nuclei and therefore occurs at very high temperatures. It is estimated that for such reactions temperature of approximately 200 million kelvins is needed.

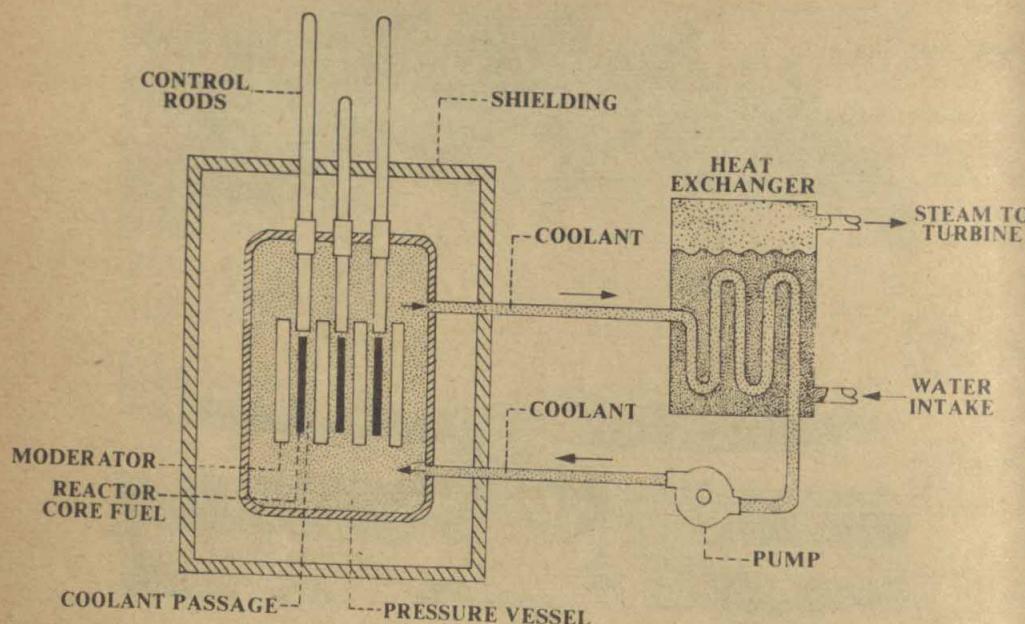


Fig. 12.8 Nuclear Reactor

The sun, our primary source of energy, derives its energy from fusion of hydrogen nuclei into helium nuclei. Highly destructive hydrogen bomb is also due to fusion reactions.

As a potential source of commercial electrical power, the fusion process has several advantages over the fission reaction. First, quantity of energy liberated in nuclear fusion reaction is much greater than in fission. Another important advantage is that fusion reaction are relatively clean in the sense that the products of fusion reaction are generally not radioactive. Contrary to this, in fission reactions products and by-products are radioactive and problem of disposal arises. So far it has not been possible to bring about a controlled fusion reaction and to safely use the heat released during the reaction.

12.9 Atomic Energy in India

In large parts of the world, atomic energy is becoming a prominent source of electrical power. In India, too, atomic energy is being used to generate electricity and to bring about improvements in industry, agriculture, medicine, and in other fields through its varied applications.

The major centre for research and development work in *atomic energy* in the country is the Bhabha Atomic Research Centre (BARC), Trombay, Bombay. It has five research reactors namely: Apsara, a 1MW swimming pool type reactor, CIRUS, a 40 MW reactor, Zerlina, a zero energy experimental reactor, Purnima, a zero energy fast reactor and Dhruva, a 100 MW reactor. Besides the reactors, the Centre has some of the most advanced laboratories and research facilities in the world.

Apart from BARC, Trombay, there are several other laboratories in the country [at Gulmarg (Srinagar) and Calcutta] which are doing nuclear research work.

Uranium and thorium are used as fuels in atomic reactors. The Uranium Corporation of India Ltd. mines and concentrates uranium at Jaduguda in Bihar. Nuclear fuel complex at Hyderabad fabricates fuel elements for nuclear power reactors.

We have seen that during fission and fusion reactions tremendous amount of energy is evolved. The most important application of atomic energy is its use for generating power. India commissioned 3-unit 420 MW Tarapur Atomic Power Station in Maharashtra in October 1969, for the first time. Three other 2-unit stations are under construction: The Rajasthan Atomic Power Station at Rana Pratap Sagar near Kota, which has an installed capacity of 440 MW, the Madras Atomic Power Station at Kalpakkam, with an installed capacity of 470 MW and the Narora Atomic Power Station in Uttar Pradesh which will also generate 470 MW. The first unit of Rajasthan Atomic Power Station has been in commercial operation since December 1973. The total nuclear power generation capacity of the country is now 1095 MW. The nuclear power programme aims at achieving an installed capacity of 10,000 MW by 2000 A.D. which would represent about 10 per cent of the power generation capacity at that time.

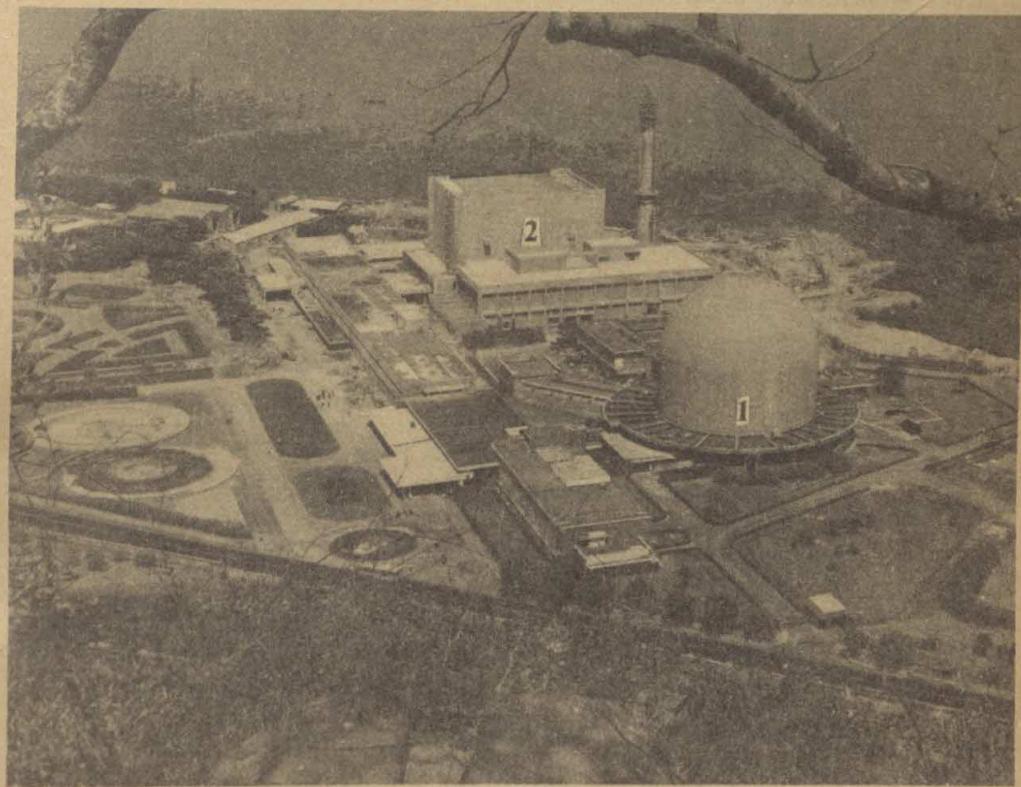
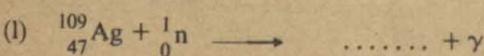
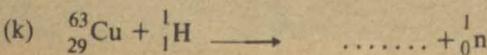
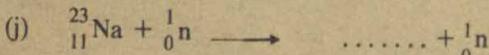
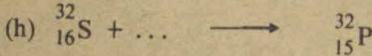
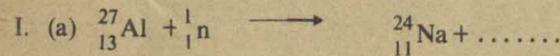


Fig. 12.9 A view of Bhabha Atomic Research Centre (Courtesy: BARC, Bombay)
(No. 1: CIRUS reactor and no. 2 : Dhruba reactor).

The power reactors being constructed at present require heavy water which is used as a moderator and coolant. To produce this rare commodity within the country four heavy water plants are under construction at Kota, Baroda, Tutticorin and Talcher. A small heavy water plant is also operating at Nangal.

EXERCISES

1. What are the renewable and non-renewable sources of energy? In view of the limited availability of non-renewable sources, suggest suitable energy sources for future needs of the country.
2. What is the difference between natural radioactivity and artificial radioactivity? Do you feel it will be possible to convert a heavy metal into gold as dreamed by Alchemists?
3. Write the properties of α , β and γ rays and show their basic differences in terms of charge, mass and penetrating power.
4. How are nuclear reactions different from ordinary chemical reactions?
5. Complete the following reactions:



6. Write a balanced equation for

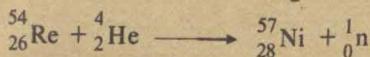
(a) α - decay of $^{226}_{88}\text{Ra}$

(b) β - decay of $^{210}_{82}\text{Pb}$

7. Supply the missing information:

<i>Nuclear symbol</i>	<i>Mass number</i>	<i>No. of protons</i>	<i>No. of neutrons</i>
(i) $^{60}_{27}\text{Co}$	—	—	—
(ii) —	24	11	—
(iii) —	—	8	8
(iv) $^{37}_{17}\text{Cl}$	—	—	—
(v) —	14	—	6
(vi) —	—	84	120

8. Write in words the meaning of the following nuclear reaction:

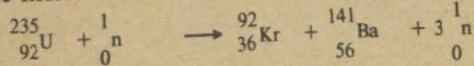


9. Define the terms:

- Radioactivity
- Half life
- Nuclear fission
- Nuclear fusion
- Chain reaction
- Radioactive tracer

- Fe-59 has a half life of 44 days. Using an initial sample of 100 mg, calculate the amount of samples still radioactive after one half-life, two half-lives and three half-lives.
- Ga-67 has a half-life of 78 hours. How long will it take for the radiation level of Ga-67 to fall to one-fourth the original level?
- The half-life of $^{60}_{37}\text{Co}$ is 5.3 years. Starting with 10.0 mg of Co-60, how much will remain after 21.1 years? (Ans. 0.625 mg).
- Does the law of conservation of mass also hold good for radioactive change? Explain with suitable examples.
- What is the law which governs the simultaneous change in mass and energy? Can you express the law mathematically? Calculate the amount of energy produced if 0.5 gram of a substance is completely converted into energy?
- What will happen if slow moving neutrons are made to strike the atoms of heavy element $^{235}_{92}\text{U}$? What is the name of the process?
- How does a fission reaction differ from a fusion reaction?

17. In brief discuss how a nuclear power plant uses a nuclear-reactor to generate electricity.
 18. The fission reaction

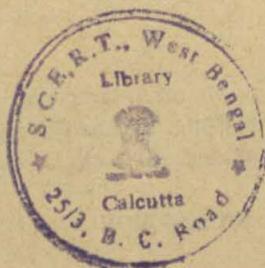


is reported to release about 175 MeV of energy per nucleus fissioned. Calculate the quantity of energy (in kilojoules) released by the fission of one gram of uranium-235.

(Hint: Use mole concept. 235 gram of uranium gives 6.02×10^{23} uranium nuclei and therefore 1 gram will give $6.02 \times 10^{23} / 235$ nuclei). Also, while calculating energy in kilojoules use the relation.

$$1 \text{ MeV} = 1 \text{ million electron volt} = 10^6 \text{ eV} = 1.6 \times 10^{-13} \text{ joules}$$

(Ans. $7.17 \times 10^7 \text{ kJ}$)



540
NCE
V2

154



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